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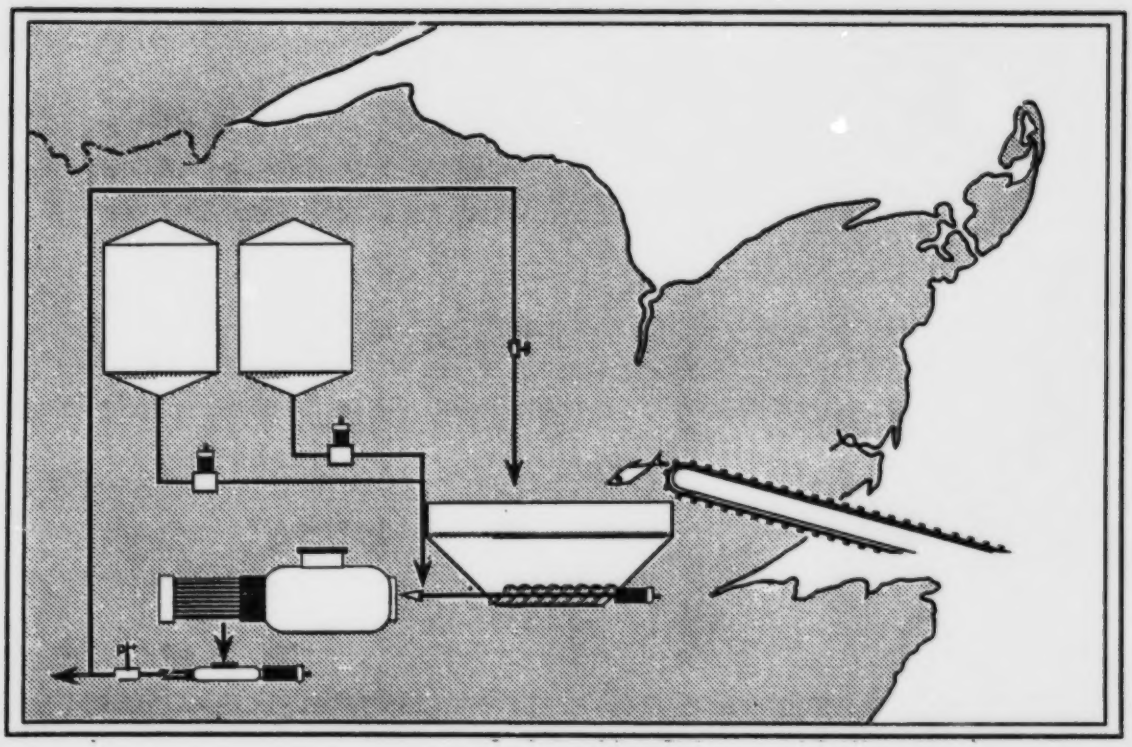
Potential utilization of fish wastes in northeastern New-Brunswick

Final report



January 1989

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New-Brunswick department of
Commerce and Technology

POTENTIAL UTILIZATION OF FISH WASTES IN NORTHEASTERN NEW-BRUNSWICK

FINAL REPORT

JANUARY 1989

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TABLE DES MATIÈRES

		Page
ABSTRACT	.....	i
1.	INTRODUCTION	1
2.	CURRENT STATUS OF FISH WASTE PRODUCTION AND DISPOSAL IN NORTHEASTERN NEW-BRUNSWICK	2
2.1	Annual and seasonal landings	2
2.2	Estimation of the volume of fish wastes produced	2
2.3	Current methods for the disposal of wastes	13
3.	FISH WASTE CHARACTERISTICS	15
4.	POSSIBLE UTILIZATION OF FISH WASTES	19
4.1	For human food	19
4.1.1	Minced fish, surimi and kamaboko	19
4.1.2	Fish protein concentrate	22
4.1.3	Edible fish oils	24
4.2	Animal feed	27
4.2.1	Grinded-frozen fish waste	27
4.2.2	Fish meal	27
4.2.3	Fish silage	31
4.2.4	Lactic acid fermentation	33
4.2.5	Fish protein hydrolysate	33
4.2.6	Fish oils	35
4.3	Utilization in agriculture	35
4.3.1	Direct application on agricultural land	35
4.3.2	Fish emulsions	36
4.3.3	Fish compost	36

4.4 Other utilizations 38

4.4.1 Pearl essence 38
4.4.2 Glue 39
4.4.3 Leather 39
4.4.4 Oils 39
4.4.5 Pharmaceutics 40
4.4.6 Biogas 41

5. POSSIBLE SOLUTIONS FOR THE UTILIZATION OF FISH WASTES IN NORTHEASTERN NEW-BRUNSWICK 42

5.1 Technical aspects 42

5.2 Markets analysis 43

5.2.1 Potential markets for fish compost 43
5.2.2 Potential markets for fish silage 47

5.3 Choice of solutions 52

6. ECONOMIC ANALYSIS OF FISH SILAGE PRODUCTION IN NORTHEASTERN NEW-BRUNSWICK .. 53

6.1 Production scenarios 53

6.1.1 Scenario 1 54
6.1.2 Scenario 2 56

6.2 Ensiling costs 58

6.2.1 Immobilizations 58
6.2.2 Fixed costs 62
6.2.3 Variable costs 64
6.2.4 Viability of ensiling 64

6.3 Refining costs 67

6.3.1 Immobilizations 67
6.3.2 Production costs 67
6.3.3 Viability of silage refining 70

6.4 Dry silage production 70

6.4.1 Immobilizations 70
6.4.2 Production costs 72
6.4.3 Viability of drying silage 73

7. ECONOMIC ANALYSIS OF FISH WASTE COMPOSTING... 74

7.1 Production scenario 74

7.2 Immobilizations 74

7.3 Production costs 77

7.4 Viability of fish waste composting 77

8. DISCUSSION AND CONCLUSIONS 80

9. RECOMMENDATIONS 84

ANNEX 1
ANNEX 2
ANNEX 3

ABSTRACT

In the early 1980's, herring de-roeing has become a major activity of the fish processing industry in northeastern New-Brunswick. This type of processing done mostly in 6 to 8 weeks in late summer uses only 4-5% of the landed herring biomass. The remaining carcasses (95-96%) cannot be used for human consumption and not even as bait; they are presently processed into fish meal and oil or, in a lesser extent, are spread on agricultural land. However, the output of herring wastes in the region in late summer is to high that traditional users are incapable of absorbing it completely. About 50% of the herring wastes produced, i.e. 15 000 to 20 000 t, are discarded in land fill sites, in dumps or at sea at a cost of 20 to 40 $/t.

Herring wastes constitute a biomass rich in proteins and oils. Fish proteins have a very good reputation for animal feed producers because of their high level of digestibility. Fish oils which have a high content in omega-3 fatty acids are associated with the prevention of cardiovascular deseases. Furthermore, fish wastes have always been recognized as good soil fertilizers.

Many technologies are presently available for processing fish wastes into usable products. However, because a very large volume of herring wastes must be processed in a very short time, complex technologies requiring large investments would not be viable in the present northeastern New-Brunswick context. Indeed, the infrastructures needed to processed the fresh wastes must have a large capacity and this large capacity will be fully used only 6-8 weeks per year.

Two technologies with a good potential have been indentified for northeastern New-Brunswick; these are composting and ensiling. Composting consists in the controlled aerobic biodegradation of organic matter. The basic process in simple and does not require energy. Besides wastes, it requires air, water and a material rich in carbohydrates. Peat moss which is very abundant in northeastern New-Brunswick is a very good source of carbohydrates. Composting units could be installed beside fish plants but a more rational approach is to concentrate operations near the source of peat moss. However, automatized composting units with a capacity of more than 100 t per day are not presently available and the potential

market is geographically limited (300 km of fish plant) and vague. Therefore, composting does not represent an attractive short-term solution for the utilization of a very large proportion of herring wastes produced. However, the use of fish compost for conditionning potato growing soils should be investigated.

Ensiling is a simple method of preserving fish wastes. The ensiling units can be automatized and adapted directly at the end of the processing lines in fish plants. Raw silage is a stable liquid product that can be stored at a relatively low cost.

In order to insure a very good quality of the product and to eliminate problems associated with the transport of a polluting matter (raw fish wastes), silage should be produced at the same rate as the raw wastes in every fish processing plant. For a fish plant producing 1 000 t of wastes in late summer, the costs of the ensiling and storage equipment is about 175 000 $. This equipment should be used during all the operational season. the value of the silage produced in this plant could amount to 125 000 $ per year. For a fish plant producing 2 000 t of herring wastes in late summer, the cost of equipments is about 300 000 $ and the value of the silage could amount to 225 000 $ per year. Ensiling would not be viable for fish plants producing less than 1 000 t of fish wastes per year. Wastes from these plants should be processed in larger ensiling units.

Raw herring silage is a product with a high water and oil content. These characteristics limit its potential scope of utilization and the geographical scale of potential markets. Thus, it is often advantageous to recuperate the oil and to concentrate the de-oiled silage. Because the costs of refining equipments are relatively high, oil recuperation and silage concentration should be done in a centralized unit. A silage refining plant with a capacity of 20 000 t per year represents an investment of about 2,2 $ millions. The value of the refined products is evaluated at 2,5 $ millions per year.

For many potential users in eastern Quebec ant the Maritimes, the cost of raw or refined fish silage when substituted to fish meal or to grinded-frozen wastes could be advantageous. Potential markets representing 63 000 to 74 000 t of raw silage per year were identified in this part of Canada. However, the penetration of these markets by fish silage produced in northeastern New-Brunswick could be difficult for the following reasons:

1. INTRODUCTION

Fish waste utilization and disposal in New-Brunswick have been the object of numerous studies. Most of them were concerned with the manipulation of liquid and solid wastes and with odour problems from fish processing and fish meal plants. Three studies (Canadian Plant and Process Engineering, 1970; Shaffner 1970; and Broderson, 1973) addressed the problems associated with liquid wastes in some of the larger fish processing plants. McLaren Atlantic (1979) studied options for the disposal of fish and shellfish wastes in southeastern New-Brunswick. More recently, Tidmarsh *et al* (1986) studied fishwaste disposal practices and options for eastern New-Brunswick. Finally, Co-Fish Ltd (1986) proposed options for a more rational use of the herring ressource of the Gulf of St.Lawrence for human consumption.

The present study was conducted in order to identify one or more economically and environmentally viable options for a better utilization of fish wastes produced in northeastern New Brunswick. The scope of the work was limited at the start in order to address more toroughly the problem of utilization or disposal of wastes produced by the herring de-roeing industry which has become in the last few years very important in this region of New-Brunswick.

The study area is limited to northeastern New-Brunswick, between the Ristigouche and Miramichi rivers. Only solid fish wastes are considered; shellfish wastes utilization being the object of other studies and liquid wastes having already been fully analysed by others. This study analyses only processing options; dumping of raw wastes at sea or on land are discussed in detail in studies cited above.

The first part of the report describes the current status of fish waste production, disposal and utilization in northeastern New-Brunswick. In the second part, we describe the composition of fish wastes produced. In the third part are presented different products and by-products obtainable from fish wastes, processing methods, possible utilization for these products and constraints related to utilization and processing. The selection of feasable options in the northeastern New-Brunswick context is made in section 5. A financial analysis of the selected options in made is the last section.

2. CURRENT STATUS OF FISH WASTE PRODUCTION AND DISPOSAL IN NORTHEASTERN NEW-BRUNSWICK

2.1 Annual and seasonal landings

Fig. 1 presents the annual evolution of groundfish and pelagic/estuarine fish landings in northeastern New-Brunswick in the last five years. Groundfish landings have been steady at about 16 000 t per year. On the other hand, pelagic/estuarine fish landings tripled in only three years, from 15 000 t in 1984 to almost 45 000 t in 1987. This large increase is explained by the expansion of the herring fishery which accounts for about 95 % of pelagic/estuarine fish landings (Table 1).

On a seasonal basis, groundfish landings are highest in May (Fig. 2); they stabilize at an intermediate level from June to October and are insignificant from December to April. On the other hand, pelagic/estuarine fish landings (mainly herring) are highest in August and September during the autumn gillnet fishery, with intermediate levels during October (purse seine fishery) and May-June (spring gillnet fishery). Herring landings are insignificant from December to April.

2.2 Estimation of the volume of fish wastes produced

The estimation of the volume of fish waste produced in Northeastern New-Brunswick was based on a survey of all fish processing plants in the study area (see list of fish plants in Annex 1). Results are summarized in Tables 2, 3 and 4 and Fig. 3.

Table 2 and Fig. 3 present the volumes of fish wastes produced by fisheries statistical district. It is estimated that a total of 57 500 t of fish wastes were produced in 1987. More than 60 % of this total was produced in Distrit 65.

Fish waste production by species is shown in Fig. 4. Shellfish wastes are presented here for comparison only. More than 80 % of fish wastes come from herring processing, followed in decreasing order by cod, redfish and plaice.

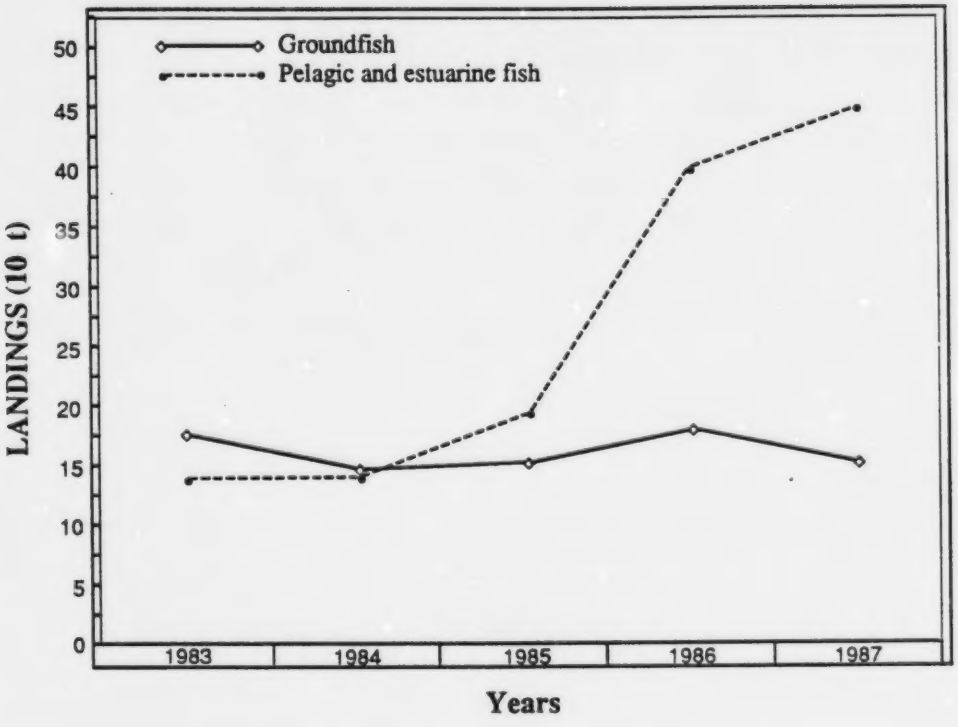

Fig. 1. Annual landings (1983-1987) of groundfish and pelagic / estuarine fish in northeastern New-Brunswick

Table 1: Species composition of pelagic/estuarine and of groundfish landings in northeastern New-Brunswick

% of pelagic / estuarine landings		% of groundfish landings	
Herring	94,8	Cod	70,2
Alewife	2,6	Redfish	19,4
Mackerel	1,3	Plaice	8,5
Smelt	1,1	White hake	1,6
Eel	< 0,1	Greenl. halibut	1,2
Striped bass	< 0,1	Pollock	0,9
Thuna	< 0,1	Tomcod	0,4
Shad	< 0,1	Halibut	< 0,1
Sturgeon	< 0,1	Yellowtail flounder	< 0,1
Capelin	< 0,1	Silver hake	< 0,1

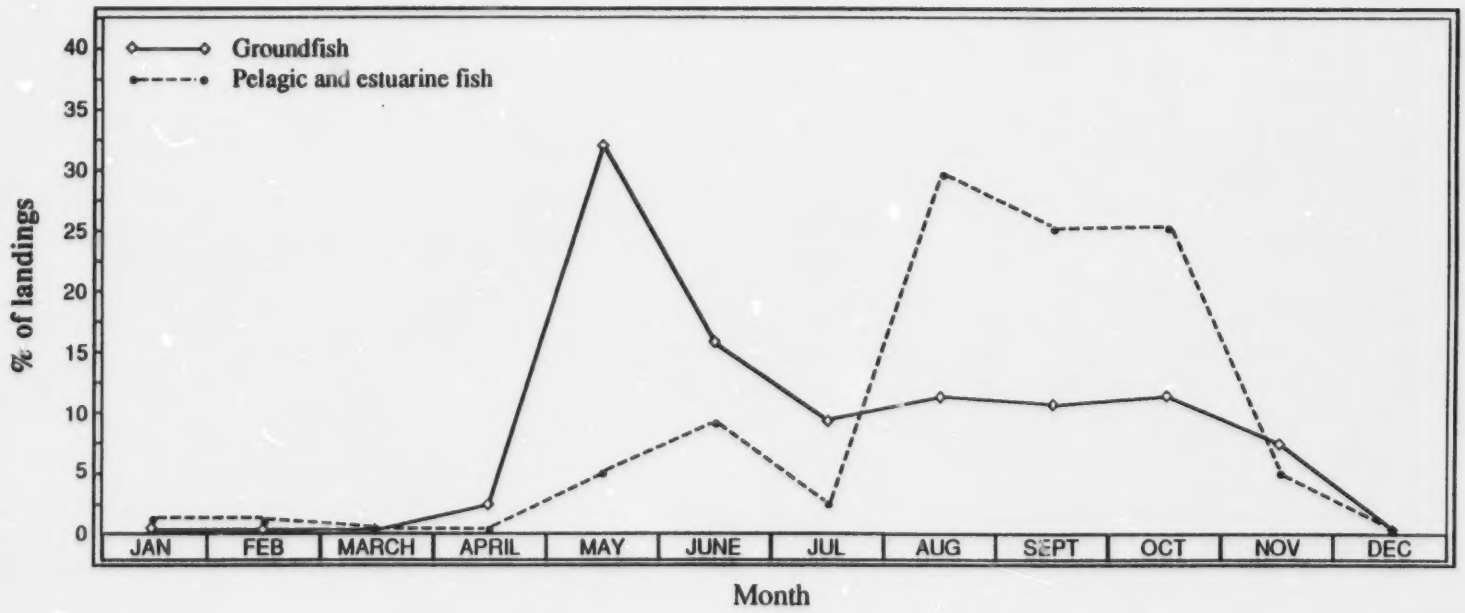

Fig. 2. Seasonal variations of groundfish and pelagic / estuarine fish landings in northeastern New-Brunswick (mean of 1984-1987)

Table 2: Volumes of fish wastes produced by fish category and fisheries district in northeastern New-Brunswick in 1987

Nº of district	Nb of plants surveyed (nb of existing plants)	Groundfish wastes produced (t)	Herring wastes produced (t)	Other pelagic / estuarine fish produced (t)	Total (t)	% of total
64	2 (2)	773	1364	159	2 296	3,9
65	13 (14)*	3 349	32 173	0	35 522	61,6
66	5 (5)	5 236	6 679	0	11 915	20,7
67	4 (4)	937	4 559	11	5 507	9,6
68	2 (2)	274	1 136	4	1 414	2,5
70	0 (1)*	?	(1 000)	?	1 000	1,7
	25 (28)	10 569	46 911	174	57 654	100,0

* One plant in district 65 and an other in district 70 did not give estimates. These two plants process large volumes of herring. Wastes produced were estimated at 2 000 t for the first plant and 1 000 t for the second.

Table 3: Yield (% of landed weight) in wastes of various processing methods used for pelagic/estuarine fishes in northeastern New-Brunswick. (V: viscera; H: head; T: tail; S: skin; B: backbone)

Species	Type of product	Nb of plants manufacturing the product	% of wastes	Type of waste
Herring	roe	22	94-95	Complete carcass
	marinated fillet	15	60-70	V-H-T-S-B
	whole, frozen	8	5	V
	fillet, frozen	7	60-70	V-H-T-S-B
	salted, headless	8	40-50	V-T
	fillet, salted	4	50	V-H-T-S-B
	fillet, fresh	3	60-70	V-H-T-S-B
Mackerel	whole, frozen	13	0	
	fillet	1	65	V-H-T-S-B
	salted	2	30	V
Alewife	whole, frozen	1	0	
	whole, salted	2	0	
	fillet, frozen	1	60-70	V-H-T-S-B
Smelt	whole or eviscerated, frozen	5	10	V
Capelin	whole, frozen	2	0	
Thuna	eviscerated	1	32	V

Table 4: Yield (% of landed weight) in wastes of various processing methods used for groundfish in northeastern New-Brunswick. (V: viscera; H: head; T: tail; S: skin; B: backbone)

Species	Type of product	Nb of plants manufacturing product	% of waste	Type of waste
Cod	fillet, frozen	14	65-70	H-T-B-S
	fillet, block	8	65-70	H-T-B-S
	salted	4	70-75	H-T-B-S
	fillet, fresh	5	65-70	H-T-B-S
Plaice	fillet, frozen	11	72-80	V-H-T-B-S
	fillet, block	5	72-80	V-H-T-B-S
	fillet, fresh	4	72-80	V-H-T-B-S
Redfish	fillet, frozen	6	75	V-H-T-B-S
	fillet, block	5	75	V-H-T-B-S
	fillet, fresh	4	75	V-H-T-B-S
Haddock	fillet, block	3	65	H-T-B-S
	fillet, fresh	1	65	H-T-B-S
Pollock	fillet, frozen	3	65	H-T-B-S
	fillet, block	1	65	H-T-B-S
Halibout	steak	5	10-20	H-T
White Hake	fillet	1	70	H-T-B-S

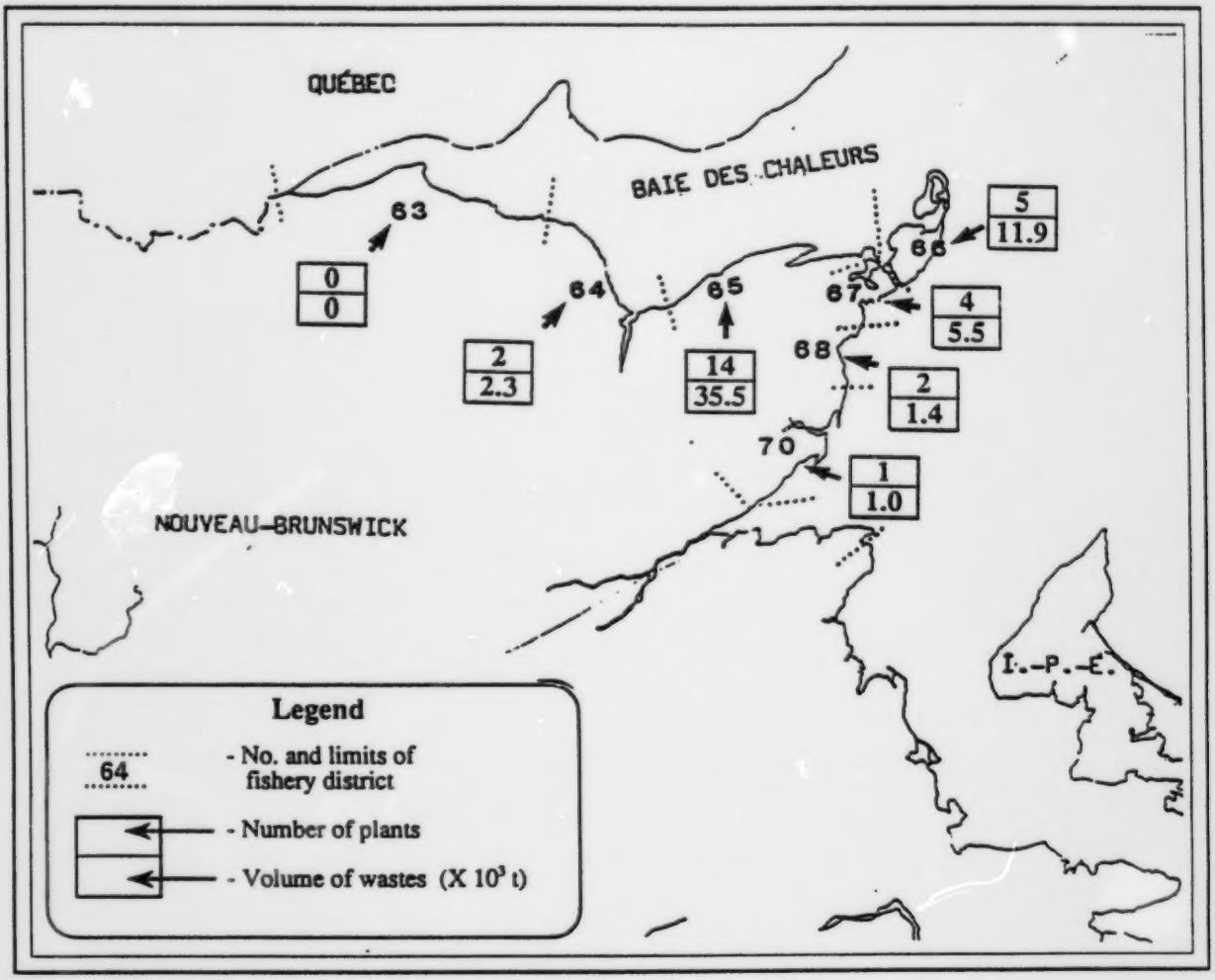

Fig. 3. Distribution of fish processing plants and volumes of fish wastes produced by fishery district in northeastern New-Brunswick

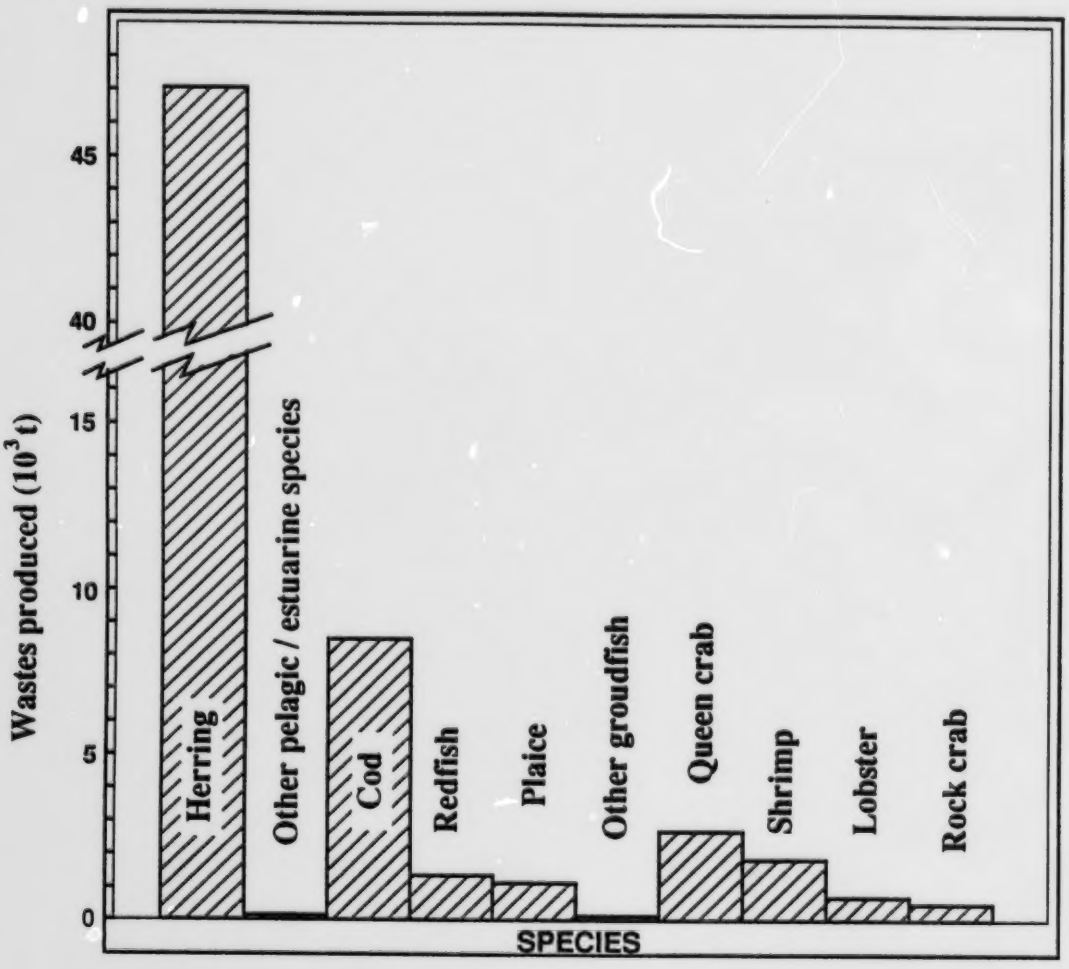

Fig. 4. Volume of fish wastes produced by species processed in northeastern New-Brunswick in 1987

Many pelagic and estuarine fishes like mackerel, smelt and capelin are sold whole and do not produce significant volumes of waste (Table 3). However, herring de-roeing produces about 95 % of waste if the carcass is not further processed.

Herring de-roeing is the principal activity of 22 of the 28 processing plants in the study area during August and September. Herring carcasses left from de-roeing during that period can not be utilized for bait or for human consumption because of the very poor quality of the material (flabby flesh and high oil content). Fillets, bloaters and cured herring are mostly produced in Spring and in October and November.

When comparing the total estimated volume of herring wastes produced in 1987 in the study area (~ 45 000 t) with herring landings for the same period (45 000 t), it is clear that a very large proportion of the herring landed was used only for de-roeing without any further processing for human consumption. Part of the very high waste yield obtained above can also be explained by the importation by land from other areas (Nova Scotia, Quebec and southeastern N.-B.) of significant volumes of herring de-roed in the area.

A very large proportion of the groundfish landed was filleted in the study area (Table 4). The waste yield for this type of processing is between 65 and 80 %, which corresponds approximately to the ratio of estimated waste production to volume landed obtain for the area (10 569 t/14 961 t = 0,71).

Monthly variations of fish waste production in 1987 in the study area are shown in Fig. 5. A first production peak occured in May-June and was composed of 50 % groundfish and 50 % herring and a much larger peak occured in August-September and was composed of 90 % herring. About 30 000 t of herring wastes were produced in a maximum of 25 days from mid-August to mid-September. During this late summer de-roeing season, more than 1 000 t of fish waste was produced per day.

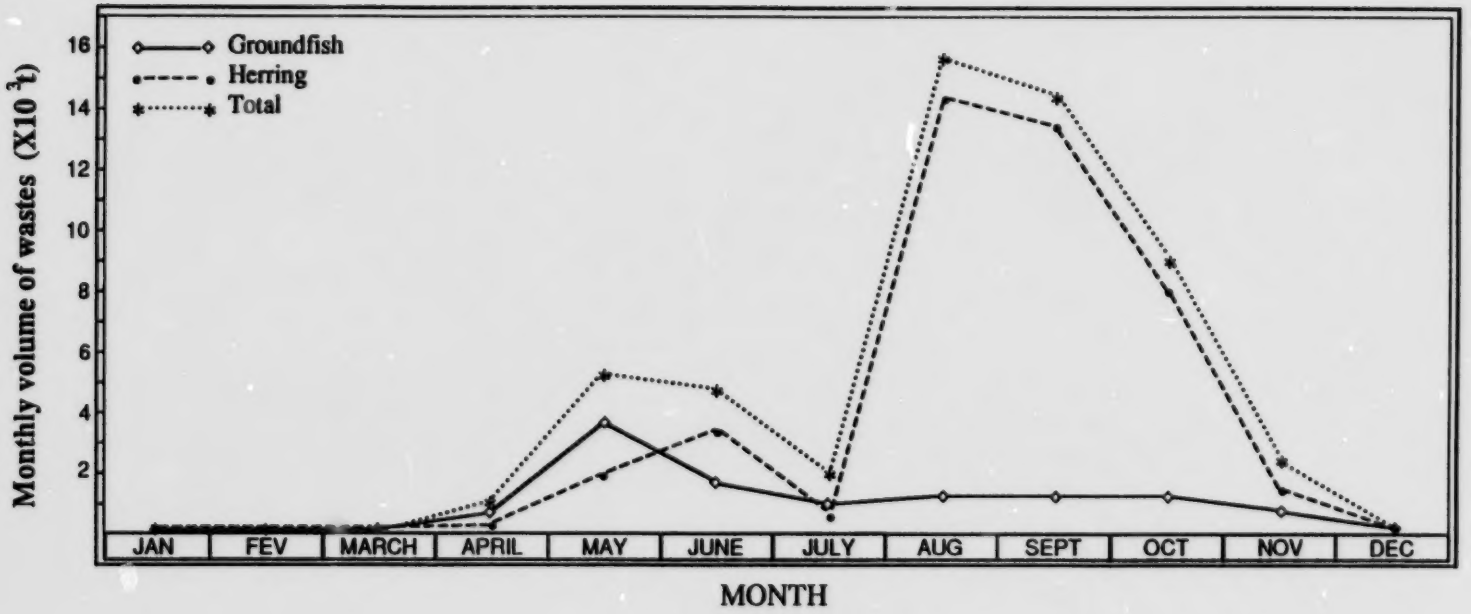

Fig. 5. Monthly variations of volume of fish wastes produced in northeastern New-Brunswick in 1987

2.3 Current methods for the disposal of wastes

Amongst the 28 fish plants in the study area, 20 shipped in 1987 part of (or all) their fish wastes to a fish meal plant; 8 plants used landfilling, 6 dumped part of their wastes at sea and part of the waste of 10 plants was spread an agricultural land.

Almost all plant managers surveyed consider that fish waste disposal is an important problem in the study area. Most of them explain the crisis by the insufficient capacity of the fish meal plants during August and September. Two processors evaluate that the fish meal plants are situated too far from their plant. Only two processors consider the curent regulations on fish waste disposal too rigid.

There are presently three fish meal plants in northeastern New-Brunswick, one in each of Districts 65, 66 and 67. One plant was built in 1965 and manufactures only herring meal and oil. The plant has one production line with a capacity of 15 t/h of raw material (240 t/day) or 40,9 t of meal and 3,4 t of oil per day (Tidmarsh *et al* 1986).

A second plant built in 1966 manufactures meal from crab waste as well as from groundfish and some herring waste. One production line is used with a capacity of 10 t/h of raw material (160 t/day) or 16,3 t of meal and 4 t of oil per day.

The third plant built in 1965, manufactures meal from crab, herring and groundfish waste. It can process 10 t/h of raw material (160 t/day) and produce 33,5 t of meal and 9,1 t of oil per day (Tidmarsh *et al* 1986).

The total maximum capacity of fish meal processing in the study area (~ 560 t/day) is much lower than the mean daily production of fish waste from mid-August to mid-

September. During that period, fish meal plants process in priority wastes produced by seven fish processing plants. The other plants must find other methods of disposal which, in 1987, were:

- land fill sites
- dumping at sea
- dumping in public dumps
- spreading on agricultural land

Fish waste disposal in northeastern New-Brunswick has become a major environmental problem in the last few years. The concentration of waste in dumps resulted in significant odour problems, attraction of vermin leading to public health concerns and major aesthetic problems. In 1987, two permits where allocated for dumping wastes at sea. The possible impacts of this activity on fish habitat have not been fully investigated. Even though processing wastes in meal and oil does eliminate problems associated with the dumping of solid wastes, it has created other problems such as the loss of blood liquor during shipping and storage before processing, offensive odours arising from the drying process and the dumping at sea of stickwater with a very high biological demand in oxygen. These problems are discussed in more detail by Tidmarsh *et al* 1986.

The three fish meal plants in the study area are operating with a technology dating from the 1960's with very high energy costs. Operators of these plants can no longer pay the fish processors for the raw material. Our survey indicates that the disposal of fish waste in the study area represents mean costs of 18 $/t for the fish processor, that is, about 1 000 000 $ per year for the whole industry. Land filling and dumping at sea cost between 20 and 40 $ per t. This means that fish waste disposal represents not only an environmental problem but also an economic problem for the fish processing industry of northeastern New-Brunswick.

3. FISH WASTE CHARACTERISTICS

The proximal composition of four types of fish wastes is shown in Table 5. Herring and redfish wastes contain about 10 % more lipids (oil) and 10 % less water than cod and plaice wastes. During the autumn gillnet fishery, the oil content of herring approaches the upper limit given in this table.

The amino-acid composition of 6 different types of protein supplements is shown in Table 6. Lysine content is important for chicken and hog feed, methionine for chicken and beef feed and tryptophane for hog feed. Fish wastes are rich in lysine and methionine.

The composition of 10 different fish oils is given in Table 7. The iodine value gives an evaluation of the insaturation of the oil; high values correspond to a high susceptibility to rapid oxydation. Unsaponifiable matters might be vitamins, sterols and esters and will represent less than 2,5 % of a good quality oil. The content of omega-3 fatty acids, and particularly eicopentaenoic (EPA) and docosahexaenoic (DHA) acids, is very high in fish oils when compared to vegetable oils. These fatty acids are associated with the prevention of cardiovascular deseases. The content in long chain fatty acids (C20-C22) is important for the chemical industry which utilizes fish oils as a source of long chain fatty acids.

Table 5: Proximal composition of various types of fresh wastes

	% Composition (humid basis)			
Waste	Humidity	Ash	Proteins	Lipids
Cod (after filleting)	78,7-85,7	2,1-6,9	11,7-15,4	0,2-0,5
Plaice (after filleting)	78,3	4,2	12,3	4,6
Redfish (after filleting)	69,2-71,0	3,4-6,6	13,2-15,6	8,0-12,7
Herring (whole)	61,8-74,0	2,0-2,4	15,5-17,9	6,7-19,8

Table 6: Composition characteristics of fish silage and other proteinic supplements (% dry matter)

PROTEINIC SUPPLEMENT	Protein (%)	Lysine (%)	Methionine (%)	Tryptophane (%)	Ca (%)	P (%)	Mg (%)	Na (%)	K (%)
Raw silage	56,00	3,60	1,30	N.D.	2,80	2,20	N.D.	N.D.	N.D.
Fish meal	69,20	3,79	1,27	0,64	1,39	1,60	0,32	0,40	0,40
Meat meal	54,10	3,11	0,70	0,32	11,60	5,48	1,09	0,77	1,43
Soya meal	52,30	3,39	0,67	0,64	0,34	0,70	0,30	0,04	2,20
Lactoserum	12,93	1,08	0,16	0,12	1,08	0,77	N.D.	2,15	0,92
Urea	281	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

N.D.: Undetermined

Table 7: Composition characteristics of various fish oils

Species	Herring	Flounder	Redfish	Capelin	Cod liver	Dog-fish liver	Mackerel	Sand Lance	Menhaden	Anchovy
Iodine value	110-140	140-150	115-125	96-128	145-180	100-128	144-152	143-153	165	182
Unsaponifiable matter, %	0,8-2,0	1,0-1,5	1,0-1,9	4-6	1,5	7,6	-	2,4	-	-
EPA, %	4-9	11-12	5-8	4-8	8-10	5	9	9-14	14-19	17
DHA, %	2-6	4-5	3-5	2,7-4,0	7-10	9	9	5-8	5-11	9
Total omega-3 Fatty acids, %	12-18	19-22	11-14	8-15	18-20	20	24	18-25	25-32	34
Total C20-C22 Fatty acids, %	40-55	40-43	46-50	49-58	45-50	54	67	45-48	25-33	35
Source	(a)	(b)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(h)

(a) Ackman, R.G. and C.A Eaton. 1966 (25) 26
(b) Ackman, R.G., and P.J. Ke. 1968. (26) 27
(c) Eaton, C.A., Ackman, R.G., and C.S. Tocher. 1975. (27) 28
(d) Ackman, R.G., and R.D. Burgher. 1964. (28) 29
(e) Canadian Institute of Fisheries Technology (Ackman, R.G.) 1986. (29) 30
(f) Ratnayake, W.N. and R.G. Ackman 1975. (30) 31
(g) Ackman, R.G., and C.A. Eaton. 1971. (31) 3
(h) Ackman, R.G. 1982. (32) 33

4. POSSIBLE UTILIZATION OF FISH WASTES

4.1 For human food

4.1.1 Minced fish, surimi and kamaboko

Methods

Eviscerated fish, fish fillets and wastes from filleting operations are placed outside a barrel with perforations of 1 to 7 mm. Pressure is applicated and the flesh enters the barrel while the skin, bones and cartilage remain outside and are discarded. The flesh obtained can be used to manufacture surimi, kamaboko, soups, sauces, pies, sausages, sticks, etc.

To produce surimi, minced fish is washed in cold water with a pH higher than 6. Excess water is discarded by centrifugation or with a press. The flesh is then chopped once more and 2,5-4,0 % salt is added with sugar, starch, polyphosphates, monosodium glutamate and other products inducing the agglomeration of proteins. The resulting paste is frozen and can be used for the production of kamaboko.

Kamaboko designates surimi paste molded by extrusion into various forms with added natural or artificial flavors and colours.

Limits and constraints

Minced fish is highly susceptible to bacterial degradation and oxydation. The process will change the colour and texture of the flesh. The best material for this type of processing is fresh groundfish wastes; pelagic fish (like herring) give a poor quality product. Surimi made from fish waste has a bad colour because of blood residus. Because of the high capital required for equipment and the high standards of the markets, surimi is generally produced from low value groundfish species for which a large scale and long term fishery is developed.

The manufacture of surimi from pelagic fish is presently under experimentation in Japan and the United States (Fig. 6). A good quality product can be obtained but the yield is low. The development of a seasonal surimi industry based on herring in northeastern New-Brunswick does not seem feasable.

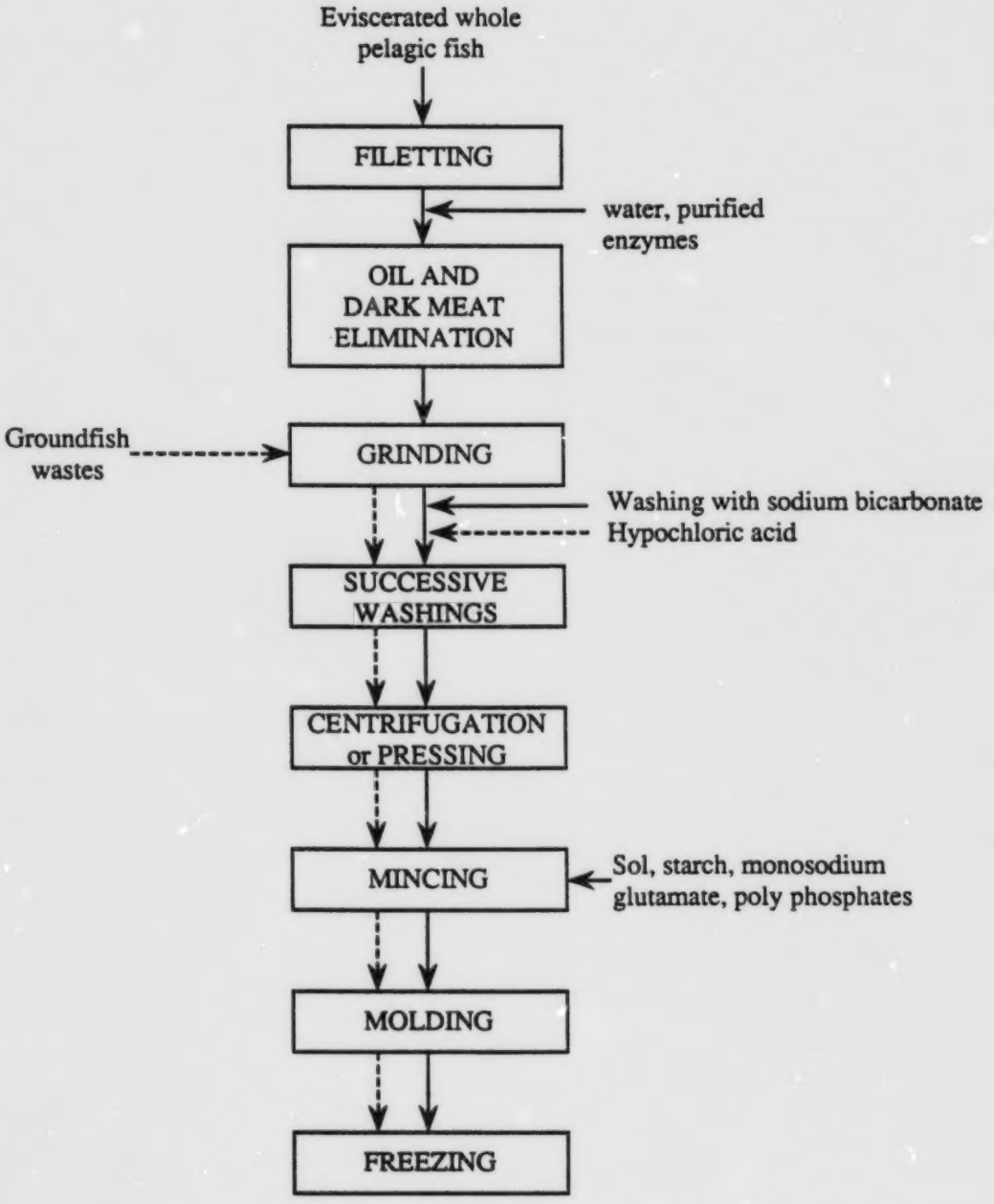

Fig. 6. Flow diagram for the production of surimi from pelagic fish (——) and groundfish (----)

4.1.2 Fish protein concentrate

Methods

Fish protein concentrates (FPC) were developed as a protein supplement for human in developing countries. These meal-like products vary in flavor and colour depending on the type of process used. In general, the raw material is grinded then the water, the oil and all components responsible for colour and odours are eliminated by a series of chemical extractions. The various processes have the following general scheme:

1° Grinding
2° Multiphase chemical extraction
3° Separation of liquid and solid phases by centrifugation
4° Distillation to recuperate solvant in liquid phase
5° Drying of solid phase
6° Bagging

The best raw material is eviscerated groundfish. Grade A FPCs consist of an off-white powder without any specific colour and odour and with a maximum fat content of 0,75 %. Grade B concentrates have a definite fish flavor and a fat content higher than 0,75 % but lower than 3 %.

Limits and constraints

The process requires sophisticated equipment, trained manpower and a large amount of capital. It does not produce odours except in the case of pelagic fish where the raw material must be cooked (Fig. 7). There are no North American markets for this substitute of vegetable flours.

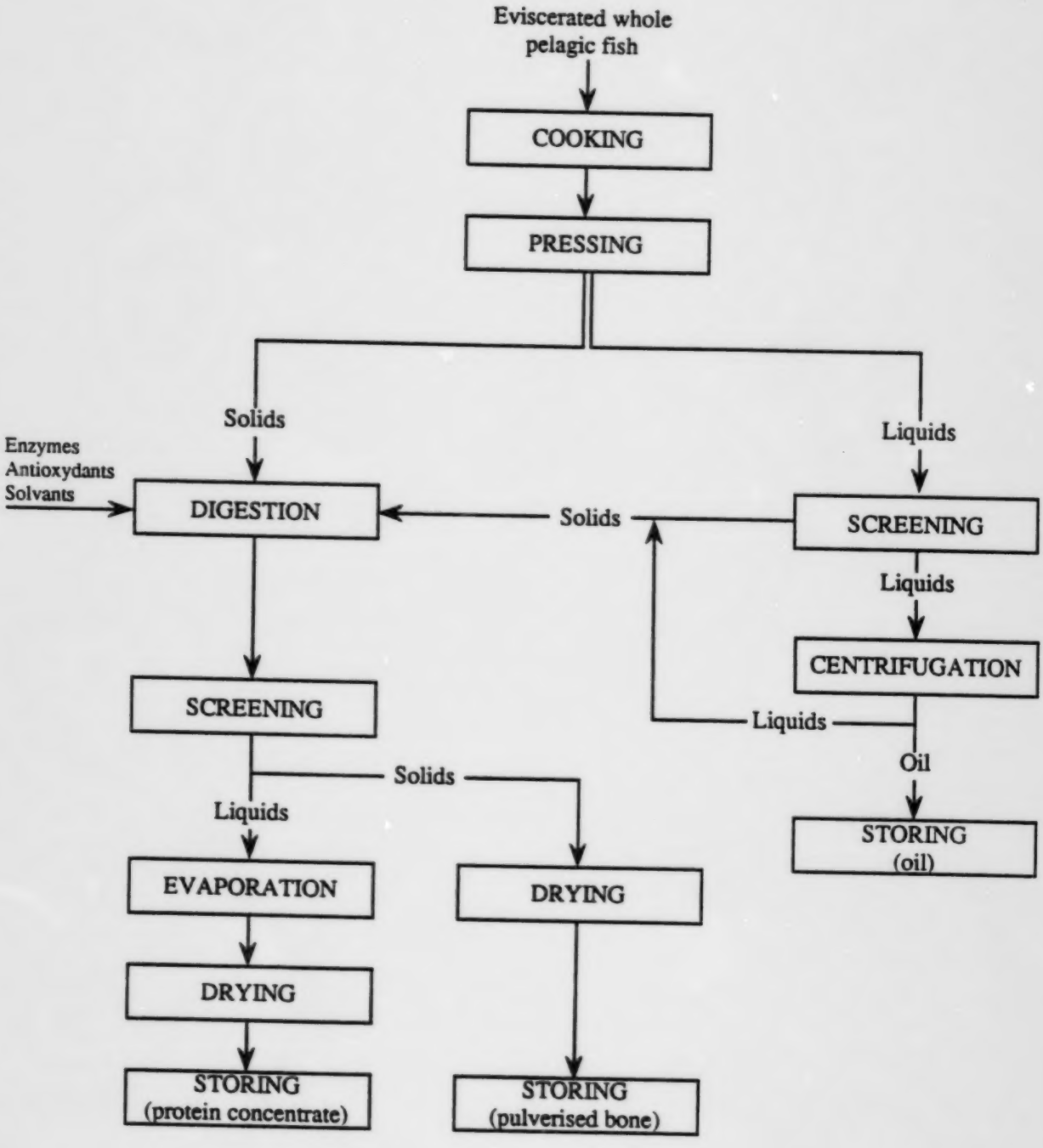

Fig. 7. Flow diagram for the production of pelagic fish protein concentrate

4.1.3 Edible fish oils

Methods

Worldwide, the largest use of fish oils is in the manufacture of edible products, particularly margarine. On this market, fish oils compete with vegetable oils and constitute a cheaper alternative. Fish oils are presently obtained from the fish meal industry. Refining of raw fish oil is usually made in five steps:

1° Preliminary refining to eliminate free fatty acids
2° Bleaching to eliminate colored matters
3° Hydrogenation under pressure
4° Final refining to stabilize flavor
5° Deodorization by vacuum distillation

To be edible, fish oils must contain less han 3 % free fatty acids, less than 2,5 % unsaponifiable matter and less than 1 % humidity.

Fish liver oils can be extracted by various methods. The most common starts with the grinding of the livers; they are then cooked at 90-95°C. The oil is separated by centrifugation. Other processes use freezing, pressing or chemical dehydratation but require the pasteurization of the final product. Edible fish liver oils (grade A) are made from fresh clean livers with no blood and other offals attached. It has a straw colour and a high vitamin A content. Grande B liver oils are used in animal feed. Grade C liver oils are used to manufacture paints and other products.

In the last few years, omega-3 fatty acids concentrates have been produced and marketed in Europe and the United States. Various refining methods have been developed:

- Fractionation by cooling
- Urea complexing
- Molecular distillation
- Supercritical extraction
- Chromatography

Presently, urea complexing is the most promising method; it is described in Fig. 8. Fish oil is split into fatty acids using alcoholic KOH or NaOH. These fatty acids are then mixed with an alcohol solution of urea to form a complex. The solution is then cooled to a low temperature in order to remove by filtration the cristallized saturated fatty acids complexes and monoglycerides. The soluble complex is broken by acidification and the polyunsaturated fatty acids are recuperated by solvent extraction and cleaned by distillation.

Limits and constraints

The marketing of fish oils other than menhadenoil for human food is presently prohibited in the United States. In Canada, the edible oil industry has in the past (1960's) used large quantities of this material but got away from its use when supplies faltered in the early 1970's. Since 1983, fish oils are not used by this industry. Futhermore, a new Food and Drug act regulation limits their utilization in edible products in Canada. For instance, this regulation restricts the percentage of herring oil to 15 % or 20 % in edible oil compositions. In Europe, fish oils are used in large quantities for the production of margarine.

The main species used to manufacture liver oils are cod, pollock and haddock. In northeastern New-Brunswick, these species are eviscerated at sea and livers are not part of the wastes produced by the fish plants. Fish liver oils production requires special and expensive equipment and must be based on a large and concentrated inshore groundfish fishery.

The manufacture of omega-3 fatty acids concentrates is in rapid expansion in Europe and the United States where their marketing is not prohibited. In Canada, the product is still awaiting approval for sale. Nevertheless, herring oil would be an excellent raw material for the manufacture of the product.

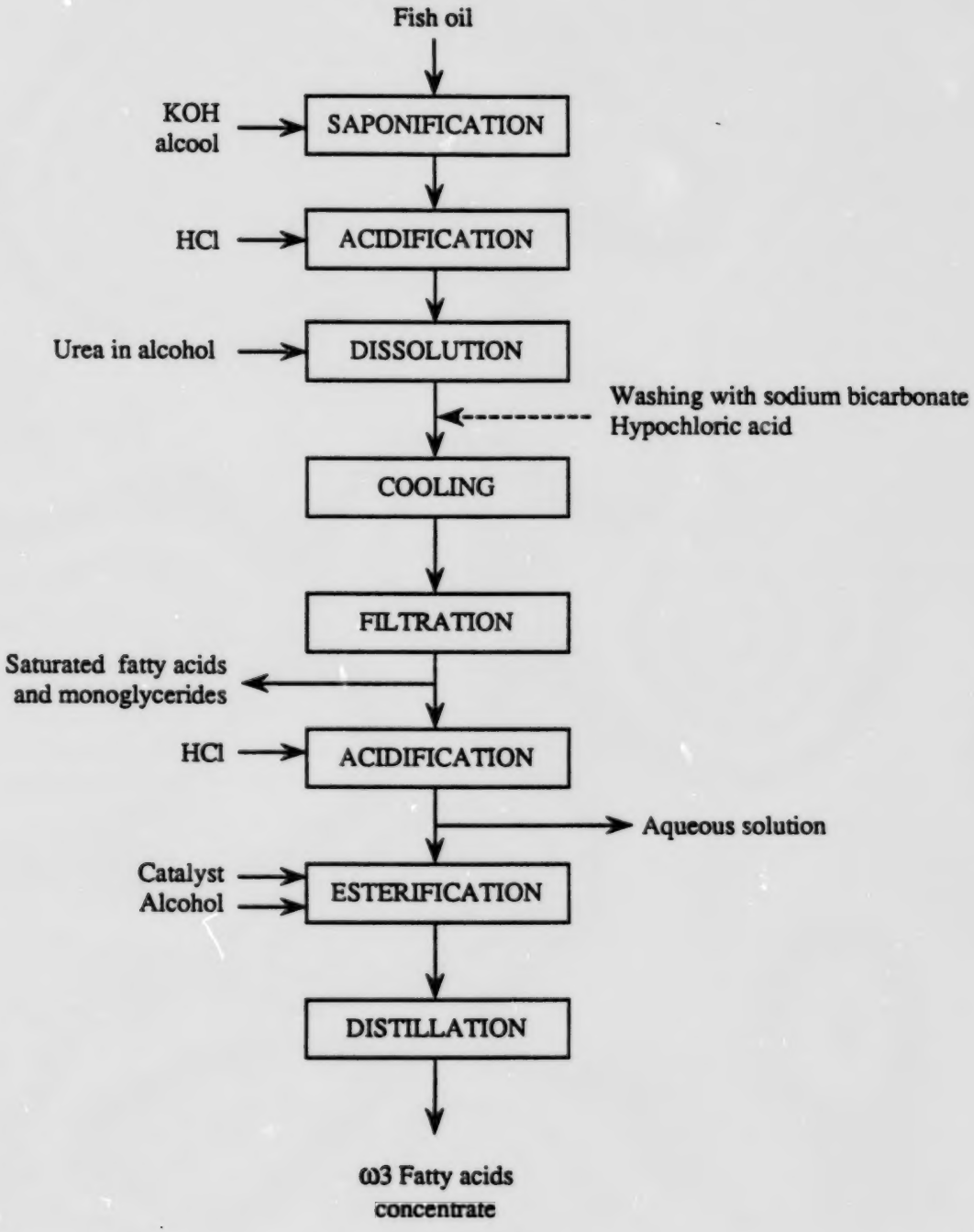

Fig. 8. Flow diagram for the production of ω3 fatty acids concentrate

4.2 Animal feed

4.2.1 Grinded-frozen fish waste

The fur and pet food industry as well as zoos and aquariums use large quantities of grinded-frozen fish waste as a raw material. Prices paid by these users (FOB freezing plant) vary between 140 and 150 $ per t. Only groundfish wastes (mainly cod) are used; frozen pelagic fish wastes become rancid during long-term storage.

The most important market for this material is the canned pet food industry concentrated in Ontario. This sector used about 11 500 t of frozen fish wastes in 1987; 70 % of this total came from the United States. This market requires white flesh wastes. The dry pet food industry uses mainly fish meal.

Mink farms use mainly moist feed and the proportion of frozen fish wastes in the formulations can reach 30 %. The potentiel market in this sector is found in Ontario, Quebec and the Maritimes. It is estimated that in 1987 Ontario and Quebec mink farms used 3 500 t of frozen fish wastes. Fox farms use mainly dry feed and the percentage of fish wastes in the diet is small.

4.2.2 Fish meal

Methods

The basic method for the manufacture of fish meal has not changed significantly since the 1960's (Fig. 9). Fish wastes are first grinded then cooked in order to facilitate the separation of oil, water and solids. The cooked paste is pressed and the solids are dryed; oil in the liquid phase is recuperated by centrifugation.

In recent plants, cookers use waste heat from other phases of the process. Stickwater is concentrated by evaporation in order to recuperate dissolved solids. Traditional dryers of the direct type where combustion gazes are injected directly in the material are replaced by

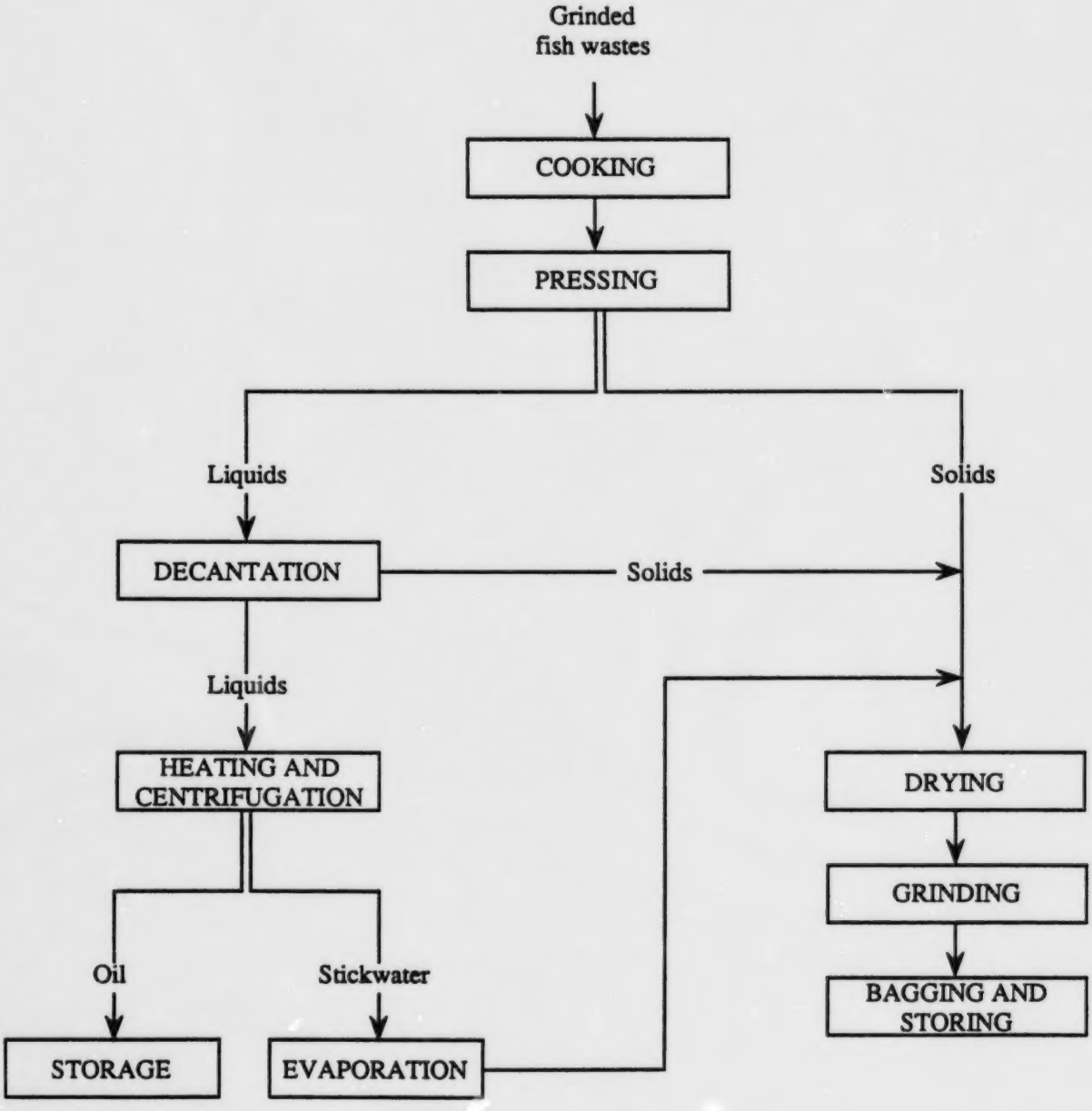

Fig. 9. Flow diagram for the production of fish meal and oil

indirect dryers in order to reduce energy costs. In plants still using direct dryers, sodium hypochlorite or others types of filters are used to limit odours in exhausts from the drying process. Presently, two of the three fish meal plants in northeastern New-Brunswick use direct-type dryers. All three have stickwater evaporators.

Fish meal utilization

Before the 1930's, fish meal was mainly used as a fertiliser. Now, it is mostly used in the manufacture of animal feed. It is an important source of proteins for hogs and chickens and is used in the formulation of feed for fur animals, pets and fish. It is not utilized by the dairy industry because milk would have a fish flavor. The wholesale price of fish meal depends largely on that of soy meal which dominates presently the protein supplement market in North America (Fig. 10). The price of these two commodities has not changed significantly for 1980 to 1987 but appear to be on an increasing trend since then. Fish meal is a relatively expensive source of proteins but its digestibility is higher than other sources.

The minimal percentage of fish meal in the formulation of feeds is about 30 kg per ton of chicken feed and 40 kg per ton of hog feed. In fish feed, the proportion is usually higher. For trouts, starter feed can contain 46 % fish meal and grow-out feed, 27 %. The dry pet food industry uses large quantities of fish meal. As a whole, the animal feed industry in Canada used 38 846 t of fish meal in 1986. In New-Brunswick the total volume of fish meal purchased is about 4 000 t per year.

Limits and constraints

Fish meal production requires special and expensive equipment. Plants are complex, require specialised manpower and have high energy costs. Existing plants in northeastern New-Brunswick use old equipment; they have high production costs and are responsible for local environmental problems (odour emissions and stickwater dumping at sea).

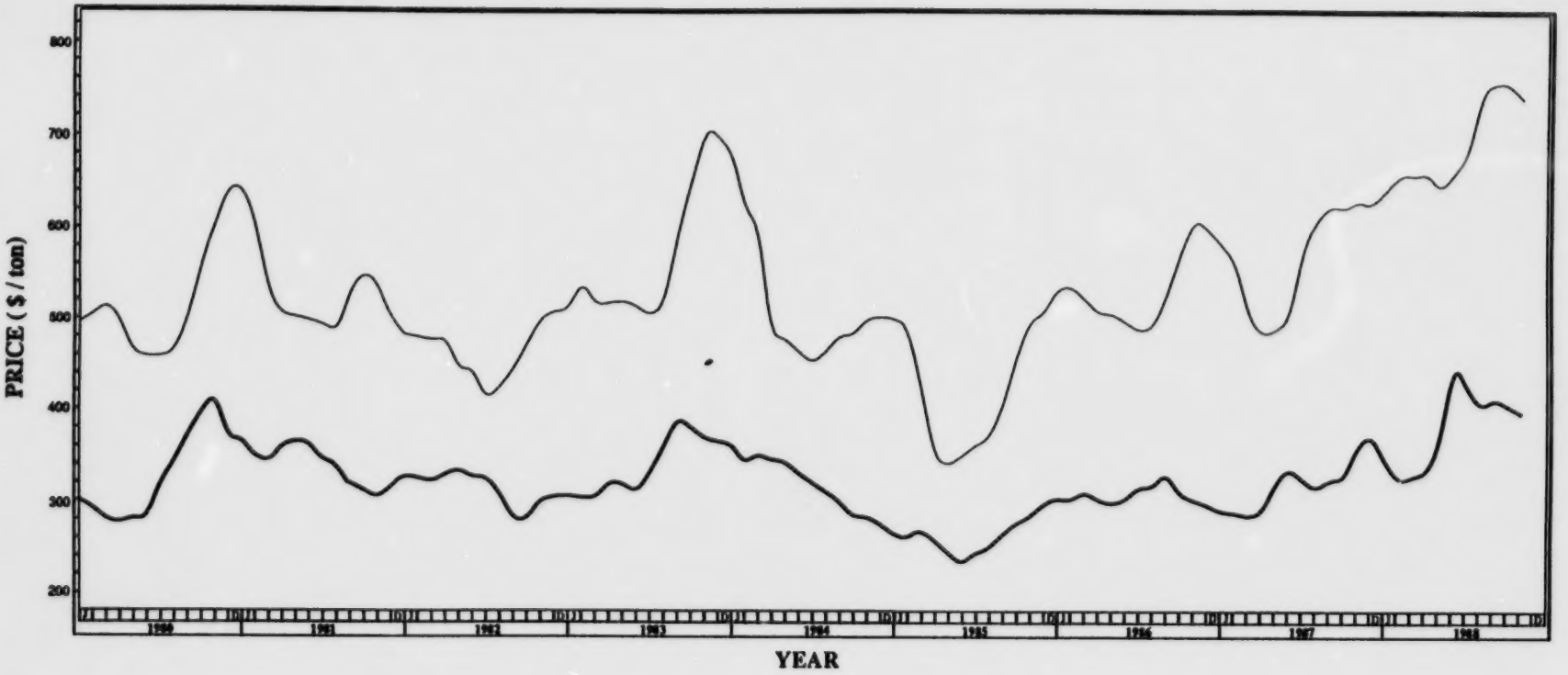

Fig. 10. Fish meal (——) and soy meal (——) wholesale price (Montreal) variations from 1980 to 1988.

4.2.3 Fish silage

Methods

Fish silage is a relatively new method in North America but has had commercial applications for more than 30 years in Scandinavia. It consists of a method of preservation of fish waste by lowering its pH. The lowered pH stops the proliferation of microorganisms responsable for the putrefaction of the fish without impeding the action of proteolytic enzymes naturally present that liquify the waste.

The first step of the process (Fig. 11) is the grinding of the waste. Acid is then added in order to reduce the pH. Liquifaction follows rapidly. Enzymatic activity can be stoped by heating at 85°C. Oil can be separated and the remaining silage can be concentrated by evaporation. Raw silage contains 70 to 80 % water, same as fish waste. The concentration process usually lowers this percentage to 50 %.

Utilization of fish silage

The principal market for fish silage in Scandinavia is the fur and salmon industries. For the mink and the fox, the percentage of raw silage in the formulations is limited to 10 % because these animals are sensitive to acidic diets. Silage with a high oil concent can and should be used because the absorption of marine oils enhances the quality of furs.

Silage can be used in hog feed. However, the oil content must not exceed 1,0 % (on a humid basis) and the use of fish silage in the diet must stop at least 30 days before slaughter in order to eliminate the fish flavor in the meat.

Silage has presently a low potential when used in chicken feed because the feeding systems used by this indusry are for dry feed only.

If its price was competitive, fish silage could replace grinded-frozen fish waste in the pet food industry.

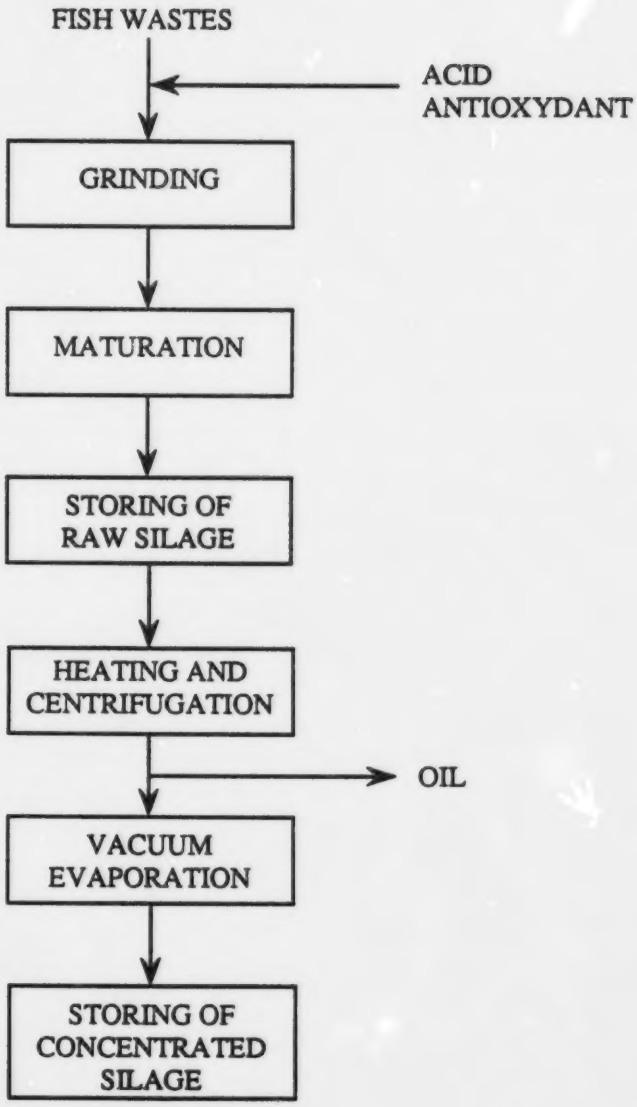

Fig. 11. Flow diagram for ensiling and refining

Raw silage rich in oil is an excellent source of proteins and lipids for the preparation of trout and salmon feed. With the rapid development of salmon farming in New Brunswick, this market is becoming very important. Raw silage could represent more than 50 % of the diet of trout and salmon.

Limits and constraints

The production of raw fish silage is a simple method.which does not require specialized manpower and does not consume lots of energy. However, shipping costs are high and markets in North America are not developed. The technology does not create any residues and odour and is non polluting.

4.2.4 Lactic acid fermentation

Lactic acid fermentation is similar in many ways to silage production. In this case, the lowering of the pH and the following liquifaction results from the mixing of lactic cultures and sugar to the grinded fish wastes. Lactic bacteria process the sugar into acid. The product obtain has a better taste than silage and, since it is less acid, could be used on a larger extent in the feed of minks and foxes. The process is however more expensive because of the relatively high cost of sugar. Even though this process has been the object of numerous experiments and patents, it has not been succesfully commercialized in Europe and North America.

4.2.5 Fish protein hydrolysate

Methods

Fish protein hydrolysate is similar to fish silage. In this process, waste liquefaction results from the addition of purified vegetable enzymes (Fig. 12). Solids are eliminated by screening. Oil is recuperated by centrifugation. The liquid phase must be pasteurized; it is

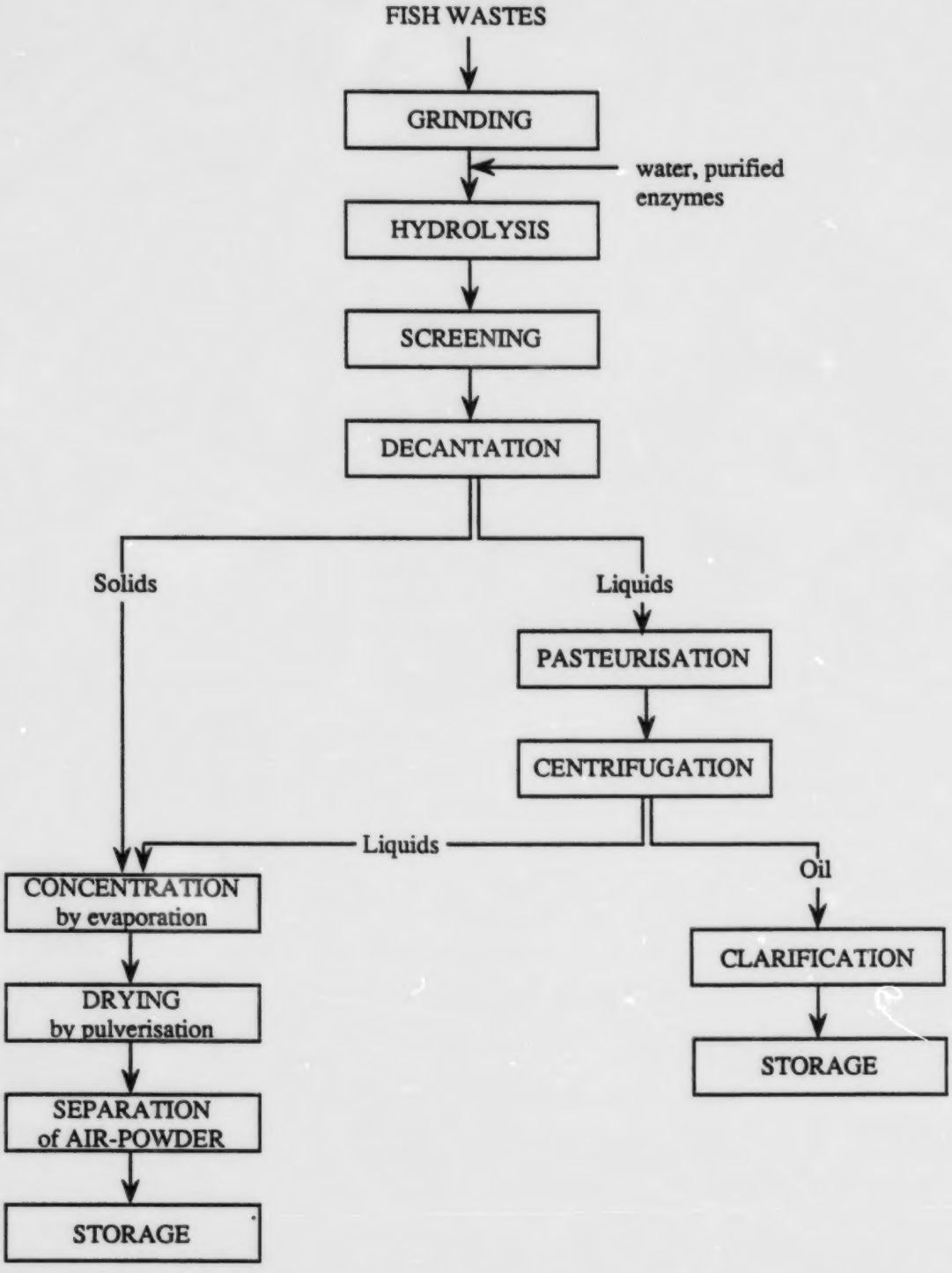

Fig. 12. Flow diagram for the production of fish hydrolysate concentrate

concentrated by vacuum evaporation and dryed by pulverisation. Many variations of this process have been experimented.

Limits and constraints

The process is still at the development phase and an economically viable solution is yet to be found. Presently, the process is expensive and requires specially trained manpower. The product could replace milk solids in chicken feed.

4.2.6 Fish oils

Fish oils, as by-products of the manufacture of fish meal, fish silage or fish protein hydrolysate, are not used in large quantities by the animal feed industry. Their refining (see section 4.1.3) is more expensive than that of vegetable oils. The most promising market for fish oils is salmon farming. Trout and salmon must be fed a diet rich in polyinsaturated fatty acids which are found in a larger proportion in fish oils than in vegetable oils. Salmon feed contains usually 6-10 % fish oil; the prefered oil is herring oil because of its specific composition. The demand for herring oil in eastern and pacific Canada should increase in the near future.

4.3 Utilization in agriculture

4.3.1 Direct application on agricultural land

Direct application of fish wastes on agricultural land is an old practice in northeastern New-Brunswick It has however largely been dismissed with the advent of chemical fertilizers and the decrease of agricultural land near fish processing plants. Because fertilizers are usually applicated in spring before planting, and because most unused wastes are produced in late summer, this practice is not an attractive solution for northeast New-Brunswick. Futhermore, the application of oil rich herring wastes can cause soil compaction and decrease soil productivity.

4.3.2 Fish emulsions

Methods

Fish emulsions sold as fertilizers in North America are presently of two main types. The first type, refered to as fish soluble nutrients, is a by-product of the manufacture of fish meal; its main ingredient is concentrated stickwater. The NPK concentration of this type of product is usually around 5:1:1. The second type of fish emulsions sold is made from concentrated silage (NPK = 5:1:1).

Utilization

The use of fish emulsions in Canada is very limited. Only one company produces an unknown volume from fish silage for the gardening market; chimical fertilizers are added to the silage. In the United States, fish emulsions are much more common but volumes sold are unknown.

The application of silage on agricultural land is presently the object of many experiments and results appear attractive. However, the oil content of the silage must be low in order to avoid soil compaction.

4.3.3 Fish compost

Methods

Composting is a process by which organic matter is biologically decomposed in controlled aerobic conditions. Many types of solid wastes can be process in this way, and particularly those rich in organic matter.

The basic method for composting fish wastes (Fig. 13) starts by grinding the wastes. A material rich in carbohydrates is mixed with the wastes and the mix is aerated. Aerobic

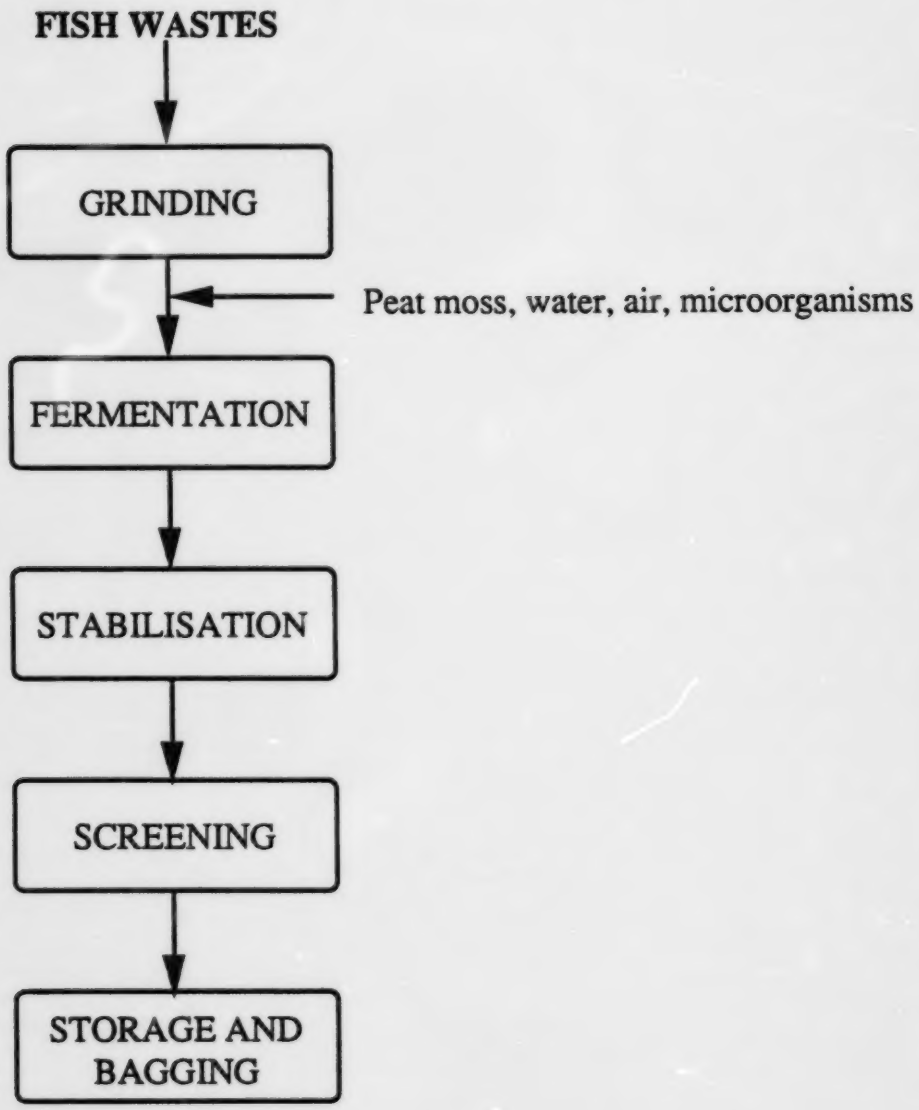

Fig. 13. Flow diagram for composting fish wastes

bacteria and fungi digest the organic matter during the fermentation phase. A stabilization phase gives a product that can be stored for long periods.

A good fish compost is odourless and weed free. It is used as a fertilizer and a soil conditionner in order to increase the soil content in organic matter, enhance soil texture, water retention and fertilizer absorption.

Limits and constraints

Composting is a simple and inexpensive process. Energy costs are very low. The product is relatively new and must compete with better known products such as manure and potting soils. Peat moss which is very abundant in northeastern New-Brunswick is an ideal source of carbohydrates for composting fish wastes. Shipping costs are however very high and limit considerably the size of the potential markets.

4.4 Other utilizations

4.4.1 Pearl essence

Pearl essence is a solution of guanine cristals produced from fish scales (herring and salmon). It is added to enamels and plastics to obtain a pearly finish. Various processes have been developped for its extraction:

- Fish scales can be placed in a water reservoir with an agitator. Centrifugation produces the sedimentation of the pearly matter. The cristals obtained are prepared in an aqueous or other solution.

- Fish scales can be suspended in gasoline. The pearl essence floating at the surface is collected and filtered to obtain guanine cristals.

- Fish scales can be digested by proteolytic enzymes. Organic solvants are added during the digestion and pearl essence is collected at the surface and filtered.

Natural pearl essence is now mostly used in the cosmetics industry. Many synthetic substitutes are very competitive in other industrial utilizations.

4.4.2 Glue

Glue can be produced from fish heads and skins. The raw material is first washed in soft water in order to rince salt and impurities. Caustic soda is added, then neutralized by hypochloric acid. The material is washed once more then heated with vapor. During heating, liquid glue is collected and transfered to an evaporator. Concentration goes on until the desired viscosity is obtaind. Finally, preservatives and deodorants are added before packing.

The production of glue from fish wastes is much less common than in the past because of the advent of new types of adhesives and the irregularity for the supply of raw material.

4.4.3 Leather

Cod, pollock and haddock skins can be processed into leather. Skins are first dehydrated by drying or adding salt. Then they are washed and submitted to quicklime in successive cycles. Cutaneous fibers are then hydrolysed by a proteolytic enzyme and are tanned. Oils are applied and the leather is dried. Finition includes coloration. This industry is not economically important because of the large volumes of animal leather on the market.

4.4.4 Oils

Fish oils are used by the tanning industry; they represent one of the principal components of the formulations used. The principal market is located in northeastern U.S.A. This market is however in decline because of the competition from asian countries and because vegetable oils are used in a larger extent.

Many products made from fish oils have industrial applications. The most common are lubrificants, corrosion inhibitors, flotting agents and additives in textiles, papers and asphalts. However, only 0,8 % of these products are derived from fish oils (McClare 1980). Despite this small percentage, fish oils have a special composition which make then particularly attractive for some special uses. For instance, they are very suitable as mold release agents in the plastic industry, as a slip agent in extrusion molding, in wax formulations and as water repellants. In the cosmetics industry, derivatives of fish oils could become cheap substitutes for the jojoba oil.

Fish oils are commonly used in the paint and varnish industry in a manner similar to linseed oil. They have the disadvantage that they require a more expensive refining process than linseed oil.

Finally, fish oils can be used for fuel. In eastern Canada, some fish meal plants have in the past prefered burning their oil instead of selling then on a depressed market. Since the decline in petroleum prices, this practice is not common. Fish oils can replace Bunker C oil without odours nor other environmental problems.

4.4.5 Pharmaceutics

Insulin can be extracted from the offals of many fishes (thuna, cod, salmon, and others). The process starts by grinding the viscera mixed with picric acid. This is then transfered in a satured solution of picric acid. Acetone is added to separate insulin picrates. When hypochloric acid and alcohol is added to the salts, hypochloric insulin is produced. Refining is done by alcaline precipitation. The yield of the process is small but some manufacturers have developed more efficient methods for which the information is confidential. The raw material must be very fresh: extraction must be done within 4 hours after death.

4.4.6 Biogas

Biogas can be obtained from the methanization of wastes rich in organic matter (potato wastes, manure, cheese-dairy wastes, etc.). Methanization is a process consisting in the anaerobic digestion of organic matter by methanizing bacteria. This is usually done in high performance digestors. The material used must be oxidized by acidophile bacteria (silage) and be characterized by simple structures such as aminoacids and fatty acids. Products obtained from the process are methane, which can be used as fuel, and a liquid effluent rich in organic matter and minerals usable as a fertilizer.

Methanization of wastes from the agrifood industry is presently made at the industrial stage. For example, McCain Foods Ltd. processes their potato wastes by methanization in their plant in Florenceville, N.B. However, there is presently no industrial plant for the methanization of fish wastes in Canada. With the recent decrease in the cost of petroleum products, energy savings do not justify by themselves the installation and operation of anaerobic digestors. Futhermore, processes applicable to wastes rich in lipids such as herring have not been the object of extensive experiments.

5. POSSIBLE SOLUTIONS FOR THE UTILIZATION OF FISH WASTES IN NORTHEASTERN NEW-BRUNSWICK

5.1 Technical aspects

The problem of fin-fish waste disposal in Northeastern New-Brunswick is basically associated to the herring de-roeing industry. This industry produces in a very short period large volumes of wastes that traditional users are incapable of processing.

Thus, the solutions for the utilization of fin-fish wastes must be based on technologies and markets applicable to oily fish. This first critera permits the eliminaiton of alternatives presently applicable to groundfish only; i.e.:

- Minced fish
- Grinded-frozen wastes
- Surimi and kamaboko
- Glue
- Leather

Many alternatives described in the previous section are complex and require expensive equipment and trained manpower. These are: fish meal, fish protein concentrates, fish protein hydrolysate and the extraction of pharmaceutical products. When these alternatives use raw fish wastes as the basic material, they do not represent an attractive solution for the utilization of herring wastes produced in northeastern New-Brunswick because the dimensions and costs of the infrastructure required to process these wastes during the peak of production would have to be very large and because these infrastructures would be used only a few weeks per year with very high operational costs.

The solution for the utilization of herring wastes must necessarily include in the first steps an inexpensive technology capable of processing wastes at the same rate they are produced into a stabilized material that can be stored at a low cost before marketing or further processing.

Composting is a technology that can do the job. Wastes can be rapidly mounted into windrows for the maturation process. During the maturation and stabilization stages, the process does not require much energy and manpower. The preparation of the compost for marketing is more expensive but can be done more gradually; the infrastructure needed for this step is more a function of the demand for the product than of the rate at which the wastes are produced. However, composting technologies presently available are still at the pre-industrial level; they have a processing capacity of about 100 t of wastes per day. Automatization is needed in order to process wastes at higher rates.

The ensiling fish wastes can also be a good solution. The process is simple and inexpensive. Raw silage can have direct commercial applications; however, the main advantage of the product is that it consists of a stabilized matter than can be stored at a low cost. Ensiling is an attractive method for keeping in stock the large volumes of herring wastes produced in late summer. This volume could then be gradually marketed or further processed in plants that are more or less expensive but that can be sized in accordance to the evolution of the demand on the markets.

The advantage of ensiling over composting is that the silage process can easely be integrated to the processing line in fish plants. Furthermore, large capacity automatic silage equipments are now available.

5.2 Market analysis

5.2.1 Potential markets for fish compost

Substitution products

In North America, there are presently no specific and well established markets for composts because this type of product is relatively new. Composts are part of a family of diversified products called soil conditionners. These products are used in order to enhance the physical quality of soils and are different from fertilizers which are used to increase the nutrient content of soils. Soil conditionners must be distinguished from potting soils which

are physically and chemically formulated for specific uses and cultivations. In the soil conditionners family we can include:

- peat moss
- bark mulch
- manure
- composts

Horticultural peat moss is considered as a good general soil conditionner. It is used mainly to enhance the physical structure of soils. It is a good water retainer put is poor in stabilized organic matter and very poor in nutrients. The North American market for peat moss in 1987 was estimated at 650 000 t. The most important users are professionals which prefer this sterile product over other types of soil conditionners.

Bark mulch is principally used for water retention. They are used in potting soils for trees and shrubs.

Manures are used to increase the organic matter content of soils. They also complement fertilization because of their relatively high nurient content. Manures are mostly used in bulk in intensive agriculture and horticulture. Some manure (chicken and sheep) is sold in bags on the gardening market.

Composts are relatively new products that have the same uses as manure. Presently, manure composts and sewage sludge composts are available on the markets. Compost have the advantages over manure of being odourless and weedfree and of containing nutrients more readily available to plants.

Fish waste composts are totally new products on the market. The only product presently available is made from shrimp wastes and peat moss. This product has the advantage of combining the qualities of peat moss with the high content in nutrients of shrimp wastes.

Potential users

Soil conditionners are bought by three main types of users:

- households/gardeners
- professional users (nursery-gardeners, landscape-gardeners, golf courses, market-gardeners, etc.)
- potting soil producers

In New-Brunswick, potential users are:

- nursery-gardeners (24 firms in 1986)
- turf producers (5 firms in 1986)
- landscape-gardeners (46 firms in 1986)
- golf courses
- potato growers (49 000 acres planted in 1987)
- horticulturists (2 500 acres planted in 1988)

The most important culture in New-Brunswick is the potato with 49 000 acres planted in 1987. This intensive culture rapidly depletes the organic matter in soils; the productivity of potato soils and the quality of crops is presently in decline. Local sources of cheap organic matter (manure) are not sufficiently large to correct this situation. Fish waste compost could be an attractive solution.

Other professional users in New-Brunswick could be interested in the new product. However these represent a very small market compared to the potato growing industry.

Households/gardeners use bagged products which are distributed through a complex distribution network. On a regional scale, there are about 100 large and small gardening centers in the Maritimes. This market can represent about 500 t of bagged compost per year. On a national scale, the major markets are in Quebec and Ontario. On these markets, the competition with other composts and manures is important (Table 8). Transportation costs to Central Canada represent a big handicap for composts produced in New-Brunswick.

Table 8: Market price[1] of various bagged composts and manures in Quebec

	$ per bag
Shrimp waste compost (45 L + 20 kg)	5,00 - 7,00
Hog manure compost (30 L)	5,00
Composted sheep manure (35 L)	4,00
Sheep manure (30 kg)	4,00

1. In general, market prices correspond to the FOB plant price + shipping costs + 20% for wholesaler and 40-50% for dealer.

More than 35 % of the market for soil conditionners is concentrated in Eastern U.S.A., with 5 millions households in 1987. Peat moss is the principal soil conditionner bought is that region. This market is very large but the selling price, is the main factor for its penetration. For instance, canadian peat moss is the most expensive peat-moss on this market and is used mostly by specialists. Because of high transportation costs, this would probably also be the case for composts produced in New Brunswick.

5.2.2 Potential markets for fish silage

Substitution products

Table 9 gives the composition of various products made with herring silage and of the principal substitution products. The potential direct uses of raw silage rich in oil are:

- production of fur bearing animals feed
- production of salmon and trout feed
- production of canned pet food

The potential uses of liquid silage with a low content of oil are the same as above and:

- production of hog feed
- production of organic fertilizers and soil conditionners
- production of biogaz

Dried silage has the same potential uses as fish meal; the above list is this extended with:

- production of dry pet food
- production of chicken feed

Oil recuperated from silage refining has the same potential uses as oils from fish meal plants (see sections 4.1.3, 4.2.6 and 4.4.4).

Table 9: Composition characteristics of herring silage and substitution products

	% humid basis			
	Humidity	Proteins	Lipids	Ash
Raw herring silage	67,0	16,0	15,0	2,0
De-oiled herring silage	78,0	19,0	1,0	2,0
Concentrated herring silage	50,0	42,0	3,0	5,0
Dry herring silage	10,0	76,0	4,0	10,0
Herring meal	10,0	71,0	6,0	13,0
Groundfish grinded/ frozen wastes	75,0	14,0	0,3	4,7

	% humid basis		
	Nitrogen	Phosphorus	Potassium
De-oiled herring silage	3,0	1,5	0,5
Concentrated herring silage	6,5	3,5	1,0
Dry herring silage	12,0	6,0	2,0
Chemical fertilizer	19,0	19,0	19,0

Fox breeding

The fox population in New-Brunswick farms in 1986 is estimated at 15 000 reproductive females and 3 000 males. This industry concentrated in northwestern N.B. produced 20 762 pelts in 1986. In Nova Scotia, Prince-Edward-Island and Gaspesie the total breeding population is estimated at 20 600 animals and the production, at 25 000 pelts

Fox feed is dry or humid. Annual intake of dry feed (90 % dry matter) is 78 kg per female, 82 kg per male and 54 kg per cub (pelt).

Raw silage or concentrated silage with oil added can make up to 10 % of the humid feed (30 % dry matter). Thus the potential market can be estimated at 800 t of raw silage for New-Brunswick and 1 700 t for Atlantic Canada (Newfoundland excluded) if raw silage is used or 1 500 t of raw silage for N.B. and 3 250 t for Atlantic Canada if concentrated silage is used. Silage would substitute grinded-frozen fish wastes in the formulation of humid feed. Dry silage could substitute fish meal in dry feed.

Mink breading

The mink population in New-Brunswick farms in 1986 was 4 500 females and 1 000 male; 13 700 pelts were sold that year. Elsewhere in Atlantic Canada, the population is estimated at 100 000 breeding animals and the production at 400 000 pelts.

Mink feed is usually humid (60 % dry matter). Annual intake is 45,5 kg per female, 90,5 kg per male and 41 kg per cub (pelt). Raw silage or concentrated silage with oil added can make up to 10 % of the feed. Thus the potential market can be estimated at 900 t of raw silage for N.B. and 2 200 t for Atlantic Canada (Newfoundland excluded) if raw silage is used or 1 750 t of raw silage for N.B. and 4 200 t for Atlantic Canada if concentrated silage is used. Silage would be a substitute for grinded-frozen fish wastes.

Hog breeding

Hog production in New-Brunswick in 1986 was 140 000 animals. The industry is concentrated in the North-West (37,1 %) and the South-East (36,7 %). In Nova-Scotia, Prince-Edward-Island and eastern Quebec, the production is about 500 000 animals. Annual feed intake is about 250 kg per animal produced and usually 10,4 kg of this is fish protein. Silage with a low oil content (< 1 %) could replace fish meal in the formulation: the potential market for N.B. can thus be estimated at 9 000 t of raw silage and, for Atlantic Canada, at 42 000 t of raw silage.

Presently, only of small number of hog farms are equiped with liquid feeding systems; however there is presently a program underway for the conversion to the liquid system.

Aquaculture

Atlantic salmon production in New-Brunswick in 1988 will reach 2 800 - 3 200 t. This industry is concentrated in the South-West. Elsewhere in Atlantic Canada (Newfoundland excluded), the production of salmon and trout is about 1 000 t per year. Humid feed for salmon could contain 50 % of raw herring silage. Concentrated silage with oil added could represent 75 % of the feed. The potential market can thus be estimated at 3 000 t of raw silage in New-Brunswick and 4 000 t in Atlantic Canada if raw silage was used or 8 500 t of raw silage for N.B. and 11 500 t in Atlantic Canada if concentrated silage was used. Only salmon sea based farms can presently use humid feed. Silage would replace fresh wastes, grinded-frozen wastes and fish meal in the formulations. This market differs from the others discussed above in that the demand shows large seasonal variations; 70 % of the needs must be met from July to September.

Pet food

There are no pet food plants in New-Brunswick . The canned pet food industry concentrated in Southern Ontario used in 1987 about 11 500 t of grinded-frozen wastes. This potential market can be evaluated at 13 400 t of raw silage (11 500 t of silage with a low oil content).

Organic fertilizers

Silage with a low oil content could be used as a fertilizer and soil conditionner in horticulture. In New-Brunswick, 2 400 ha are planted annually with potatos and other vegetables. An application rate of 150 kg of nitrogen per hectare corresponds approximately to 5 t of raw silage per hectare. Thus, this potential market could be very important.

Fish meal markets

Dry silage has a composition similar to fish meal. However, its does not have the same colour and texture nor the same nutritional value. It is presently difficult to determine to what extent dry silage could be marketed on the well developed fish meal markets. This potential must not be eliminated because it could be very important.

Fish oil markets

Oil recuperated from silage refining has usually a high content in free fatty acids. This is a major disadvantage when compared with oils recuperated from the standard fish meal process because oil refining is expensive. Thus, marketing oils from silage on the traditional fish oil markets could be difficult.

5.3 Choice of solutions

From the technical point of view, the two most attractive solutions for the utilization of herring wastes produced in north-eastern N.B. are composting and ensiling production. However, the market analysis made above shows that potential markets for herring composts are vague and uncertain; it is most unlikely that these markets will develop sufficiently in the near future to absorb most wastes available. In the case of silage, potential markets in New-Brunswick are estimated at 13 000 - 19 000 t of raw silage and, in Atlantic Canda, at 63 000 - 74 000 t. These numbers are impressive but must be taken with care because most potential users do not know the product and are not equipped to manipulate it. Factors permitting a good penetration on these potential markets are:

- a constant and high quality of the silage produced
- a competitive price
- a constant and secure supply

If these conditions can be respected, silage represents the most attractive solution for the utilization of fish wastes produced in north-eastern New-Brunswick. As for composting, this approach could represent an attractive solution for some fish processing plants but not for the whole industry.

6. ECONOMIC ANALYSIS OF FISH SILAGE PRODUCTION IN NORTHEASTERN NEW-BRUNSWICK

6.1 Production scenarios

Two basic scenarios are possible for the production of fish silage:

1° Production in made in a centralized plant
2° Production in integrated in the normal operations of the fish plant

Decentralization of raw silage production is the most attractive scenario for the following reasons:

- In order to penetrate potential markets, fish silage must be of a very high quality. Available silage equipments enable the processing of wastes at the same rate as they are produced, without any delays, when integrated to the fish processing line. On the other hand, centralization of silage production means delays in recovery, shipping and processing of wastes. In the case of herring carcasses manipulated in late summer, even short delays can be responsible for a poor quality of silage.

- Silage equipments can be integrated to the fish processing line. They do not occupy a large surface and the process does not require much energy and manpower. Thus, decentralized raw silage production utilizes existing infrastructures and manpower.

- Decentralization eliminates the need to transport and manipulate a polluting material (raw wastes). It is more advantageous on the environmental point of view.

- With decentralization, the fish plant can beneficiate from the value added to raw wastes. With centralization, if the silage producer does not pays for the wastes, the fish plants do not beneficiate from the added value, and if the silage producers pays for the wastes, the product is less competitive because of the added production cost.

In the case of silage refining, the only possible scenario is the centralization of production. Equipment costs are much higher than for raw silage production and the

threshold of profitability of this type of operation (more than 10 000 t of raw silage refined per year) is out of the reach of any single fish processing plant.

6.1.1 Scenario 1

The first production scenario studied is given in Table 10. The following assumptions were used:

- Fish processing plants in northeastern N.B. produce 20 000 t of raw silage annually. 70 % of this volume is produced from mid-August to mid-September; the rest in produced in May, June and October.

- Storage tanks for raw silage are not heated and must be emptied by the end of December.

- The silage refining plant processes a maximum of 2 500 t of raw silage per month.

- The yield is 38 t of concentrated silage (50 % dry matter) and 14 t of oil for every 100 t of raw herring silage processed.

- The refined products are sold at a constant rate during 12 months.

The simulations made in Table 10 gives usefull informations on the size of equipments needed:

- The maximum storage capacity required for raw silage is 7 600 t (in September). This capacity is used during only two months.

- The transfer of raw silage from the fish plants to the refining plant must be made at a rate of 3 200 t per month from August to December.

- The maximum storage capacity for raw and concentrated silage and for oil in the refining plant is 6 500 t (in December).

Table 10: First scenario for ensiling/refining fishwastes in northeastern New-Brunswick

	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar	Apr.	May	June	Jul.
Fish Plant												
Volume of raw silage(X 10^3 t)												
In tanks, start	0,0	3,8	7,6	6,4	3,2					0,0	2,0	2,5
Produced	7,0	7,0	2,0	0,0	0,0					2,0	2,0	0,0
Transfered to refining	3,2	3,2	3,2	3,2	3,2					0,0	1,5	2,5
In tanks, end	3,8	7,6	6,4	3,2	0,0					2,0	2,5	0,0
Refining plant												
Volume of raw silage(X 10^3 t)												
In tanks, start	0,0	1,9	2,6	3,3	4,0	4,7	2,2				0,0	0,0
Transfered from fish plant	3,2	3,2	3,2	3,2	3,2	0,0	0,0				1,5	2,5
Refined	1,3	2,5	2,5	2,5	2,5	2,5	2,5				1,5	2,5
In tanks, end	1,9	2,6	3,3	4,0	4,7	2,2	0,0				0,0	0,0
Volume of concentrated silage and oil(X 10^3 t)												
In tanks, start	0,4	0,2	0,6	0,8	1,4	1,8	2,2	2,4	1,5	0,6	0,0	0,0
Produced	0,7	1,3	1,3	1,3	1,3	1,3	1,1	0,0	0,0	0,0	0,8	1,3
Sold	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,6	0,8	0,9
In tanks, end	0,2	0,6	0,8	1,4	1,8	2,2	2,4	1,5	0,6	0,0	0,0	0,4

- The total tank capacity needed for the scenario is 14 100 t for a production of 20 000 t of raw silage.

- A total of 14 800 ton-month of silage must be heated from December to April.

Scenario 1 was built as a compromise between storage capacity and the size of the refining equipments (wich are the two most expensive items). For a comparable refining capacity, a scenario in which raw silage would be transfered to the refining plant at the same rate it is refined would result in an over all decrease in needed storage capacity of about 12 % but fish plants would have to heat silage during winter.

On the other land, a scenario where raw silage is transfered to the refining plant at the same rate it is produced would not result in a significant change in storage capacity because fish plants would have to maintain a minimum tank volume.

A scenario where the refining capacity is increased to 3 200 t per month would result in a 12 % decrease in needed storage capacity but much higher costs for the refining equipment.

Finally, a scenario where only volumes marketed in the month are refined in the previous month would result in a significant increase in storage capacity with a small decrease in refining equipment costs.

6.1.2 Scenario 2

The second scenario studied is based on the same assumptions as the first except that raw silage production is limited to the period from mid-August to mid-September (Table 11). For this scenario, the maximum tank capacity required is 23 000 t, i.e. a 137 % increase compared to scenario 1. A total of 28 800 ton-month of silage must be heated in winter, i.e. a 100 % increase compared to scenario 1. The refining plant operates two months longer during winter. The rate of transfer of raw silage from fish plants to the refining plant is 25 % higher in this scenario.

Tableau 11: Second scenario for ensiling/refining fish wastes in northeastern New-Brunswick

	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar	Apr.	May	June	Jul.
Fish plant												
Volume of raw silage(X 10^3 t)												
In tanks, start	0,0	6,0	12,0	8,0	4,0							
Produced	10,0	10,0	0,0	0,0	0,0							
Transfered to refining	4,0	4,0	4,0	4,0	4,0							
In tanks, end	6,0	12,0	8,0	4,0	0,0							
Refining plant												
Volume of raw silage(X 10^3 t)												
In tanks, start	0,0	2,7	4,2	5,7	7,2	8,7	6,2	3,7	1,2			
Transfered from fish plant	4,0	4,0	4,0	4,0	4,0	0,0	0,0	0,0	0,0			
Refined	1,3	2,5	2,5	2,5	2,5	2,5	2,5	2,5	1,2			
In tanks, end	2,7	4,2	5,7	7,2	8,7	6,2	3,7	1,2	0,0			
Volume of concentrated silage and oil(X 10^3 t)												
In tanks, start	0,0	0,0	0,4	0,8	1,2	1,6	2,0	2,4	2,8	2,5	1,6	0,5
Produced	0,7	1,3	1,3	1,3	1,3	1,3	1,3	1,3	0,6	0,0	0,0	0,0
Sold	0,7	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,5
In tanks, end	0,0	0,4	0,8	1,2	1,6	2,0	2,4	2,8	2,5	1,6	0,5	0,0

6.2 Ensiling costs

6.2.1 Immobilizations

A diagram of the ensiling unit in the fish processing plant in shown in Fig. 14. The equipment needed is the following:

- on feeding hopper
- one grinder/mixer
- two dosing pumps
- one acid tank
- one antioxydant tank
- one silage pump
- one pH sensor
- pipes, valves and fittings

The price for a prefabricated, automatic unit, including shipping and setting up is:

- for a maximum capacity of 2 t of wastes per hour: 100 000 $
- for a maximum capacity of 6 t of wastes per hour: 150 000

Raw silage is stored in tanks outside the fish plant. According to scenario 1, tank capacity must correspond to approximately 60 % of the total volume of wastes produced from mid-August to mid-September. The tank plant is illustrated in Fig. 15. Its cost is estimated at 100 $ per t of storing capacity. Table 12 gives the estimated cost for tanks for various daily ensiling capacities.

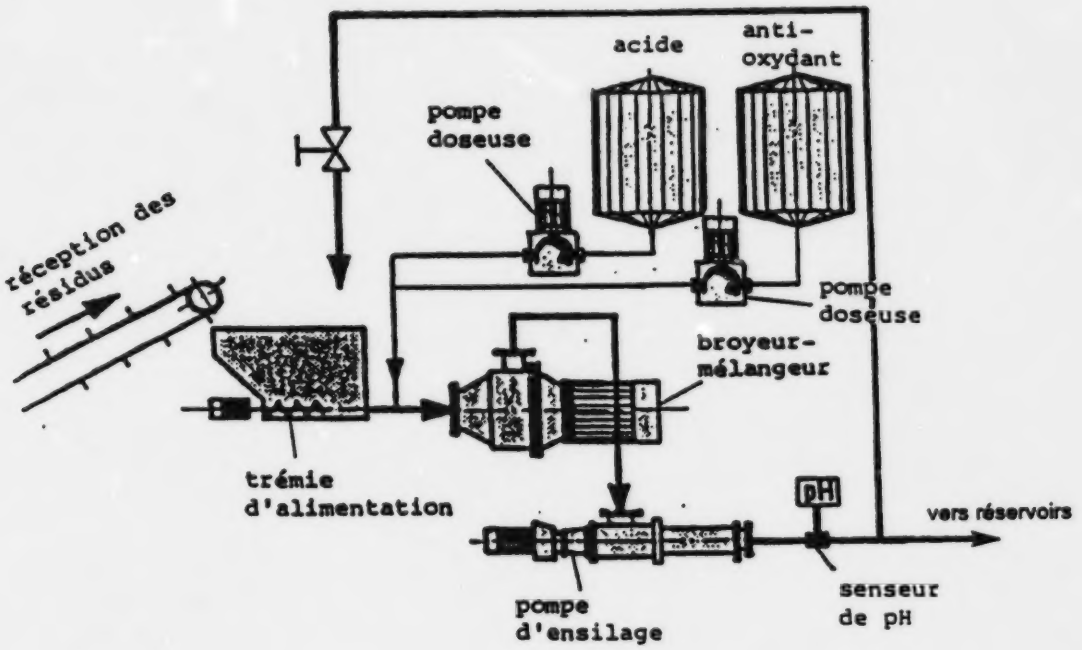

Fig. 14. Flow diagram for the production of fish silage

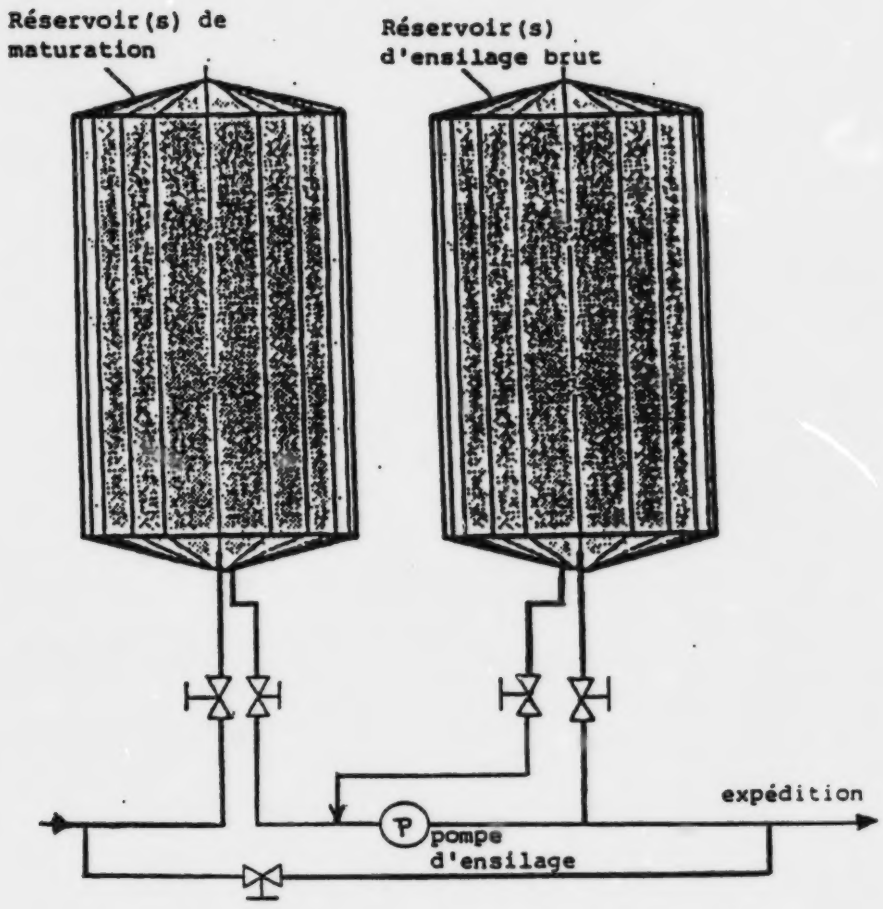

Fig. 15. Flow diagram for the fish silage tank unit

Table 12: Estimated immobilization costs for ensiling units of various capacities set up in fish processing plants

Capacity (tons of raw wastes per day)	Maximum storing capacity[1] (t)	Cost of ensiling equipment ($)	Cost of tanks system[1] ($)	Total cost ($)
150	2 250	150 000	225 000	375 000
100	1 500	150 000	150 000	300 000
50	750	100 000	75 000	175 000
25	375	100 000	37 500	137 500

1. Fifteen days production.

6.2.2 Fixed costs

Fixed ensiling costs were estimated for various ensiling capacities and for two scenarios:

- Scenario 1: 70 % of the production is made between mid-August and mid-September

- Scenario 2: 100 % of the produciton is made between mid-August and mid-September

The following assumptions were made:

- Ensiling equipment are financed by a 10 year loan and tanks, by a 20 years loan. Interest rate is 13 % per year.

- Depreciation is 10 % per year for equipment and 5 % per year for tanks.

- Insurance costs are 2,5 % of total immobilization costs and maintenance costs, 5,0 % of these costs.

- Required manpower does not vary with ensiling capacity. For scenario 2, one person is needed full time for 1 month and half time for 3 months. For scenario 1, costs of one halftime person for 3 months are added.

The unit fixed costs ($/t) calculated in Table 13 differ considerably between the two scenarios and with the ensiling capacity. They vary from 73 $ per ton for an ensiling unit with a capacity of 25 t per day operating only two months per year to only 21,34 $ per ton for an ensiling unit with a capacity of 150 t per day operating in late spring, late summer and early autumn.

Table 13: Estimated fixed production cost of raw silage for various production capacities

	Cost (000 $)							
Type of plant	1	2	3	4	5	6	7	8
Daily capacity (t)	150	150	100	100	50	50	25	25
Annual production	4 300	3 000	2 850	2 000	1 425	1 000	715	500
	Scénario 1	Scénario 2	Scénario 1	Scénario 2	Scénario 1	Scénario 2	Scénario 1	Scénario 2
Fixed costs								
Interests :								
- equipment	11,9	11,9	11,9	11,9	7,9	7,9	7,9	7,9
- tanks	20,4	20,4	13,6	13,6	6,8	6,8	3,4	3,4
Depreciation:								
- equipment	15,0	15,0	15,0	15,0	10,0	10,0	10,0	10,0
- tanks	11,3	11,3	7,5	7,5	3,8	3,8	1,9	1,9
Insurance	9,4	9,4	7,5	7,5	4,4	4,4	3,4	3,4
Maintenance	18,8	18,8	15,0	15,0	10,0	8,8	6,9	6,9
Labor	5,0	3,0	5,0	3,0	5,0	3,0	5,0	3,0
Total	91,8	89,8	73,5	73,5	46,7	44,7	38,5	36,5
Unit cost ($/t)	21,34	29,99	25,79	36,75	32,77	44,70	53,84	73,00

6.2.3 Variable costs

Variable costs for ensiling do not vary with plant capacity. They are estimated in Table 14; they amount to 44,00 $ per t of raw silage produced.

6.2.4 Viability of ensiling

Table 15 gives the estimated cost for potential users of raw silage as a function of the distance between the user and the ensiling unit. Silage produced in low capacity units would be more expensive than the estimated replacement value of silage for potential users in New-Brunswick. However, for larger capacity units, the geographical scale of the potential market is much broader.

These results suggest that ensiling could be a profitable activity for fish plants producing wastes at a rate of more than 2 000 t per year only during the herring de-roeing season and for fish plants producing more than 1 300 t of wastes per year with a good proportion of this outside the de-roeing season. Potential markets for raw silage would be limited to areas less than 400-500 km from the fish plant.

From the results of the fish plant survey discussed in section 2.2, it is evaluated that a maximum of 14 fish plants in northeastern N.B. produce wastes in volumes large enough to justify the setting of ensiling equipment. Five of these plants ship their wastes in priority to fish meal plants. The other 14 plants that produce small volumes of wastes account for a total of about 8 000 t per year and about 300 t per day during the de-roeing season.

Table 14: Estimasted unit variable costs of herring wastes ensiling

Item	Cost ($/t of raw silage)
Wastes	0,00
Shipping of wastes	0,00
Formic acid, 3,5 %, 1,20 $/kg	42,00
Antioxydant, 200 ppm, 7,50 $/L	1,50
Energy, 10 kwh/t, 0,05 $/kwh	0,50
TOTAL	44,00

Table 15: Comparison of the cost of raw silage for potential users and of the replacement value of raw silage when substituted to fish meal

Distance between plant and user (km)	Replacement value[2] ($/t)	Annual production (t) Capacité (t/jour)	Cost for user[1] ($/t) Type of plant 1 4 300 150	2 3 000 150	3 2 850 100	4 2 000 100	5 1 425 50	6 1 000 50	7 715 25	8 800 25
0	112,00		75,14	85,09	80,23	92,86	88,29	102,01	112,52	117,00
100	112,60		81,64	91,59	86,76	99,36	94,79	108,51		
200	113,17		88,14	98,09	93,26	105,86	101,29	115,01		
300	113,77		94,64	104,59	99,76	112,30	107,79			
400	114,36		101,14	111,09	106,26	118,86	114,29			
500	114,95		107,64	117,59	112,76		120,80			
600	115,54		114,14		119,26					
700	116,13		120,64							

1. Cost to user = production cost + 15% + transportation cost (0,065 $/t - km)
2. Replacement value = 80 % of fish meal cost ($/kg of protein) shipped to user (0,35 $/t-km) multiplied by the silage content in proteins (kg/t).

6.3 Refining costs

6.3.1 Immobilizations

Silage refining is done in a new centralized plant. The raw material used is raw silage produced by local fish plants and by an ensiling unit set beside the refining plant. The refining plant is automatized and can process 120 t of raw silage per day (6 t per hour). In Scenario 1, 20 000 t are processed from mid-June to mid-February to produce 7 600 t of concentrated silage (50 % dry matter) and 2 800 t of oil (Table 10). In Scenario 2, 20 000 t are processed from mid-August to mid-April (Table 11).

The refining equipment is shown in Fig. 16. The price for an automatized system, including shipment and setting up is estimated at 1 500 000 $. A building of 140 m2 is needed at a cost of 100 000 $. Tank capacity for raw silage, concentrated silage and oil is in Scenario 1, 6 500 t at a cost of 600 000 $ and, in Scenario 2, 10 300 t at a cost of 950 000 $.

6.3.2 Production costs

Fixed costs were estimated using the same assumptions as for ensiling (see section 6.2.3). They are given in Table 16. Manpower requirements and costs are as follows.

- full time manager		35 000 $
- full time quality inspector		27 000 $
- full time worker		20 000 $
- part time worker		26 000 $
- part time administration		10 000 $
	Total	128 000 $

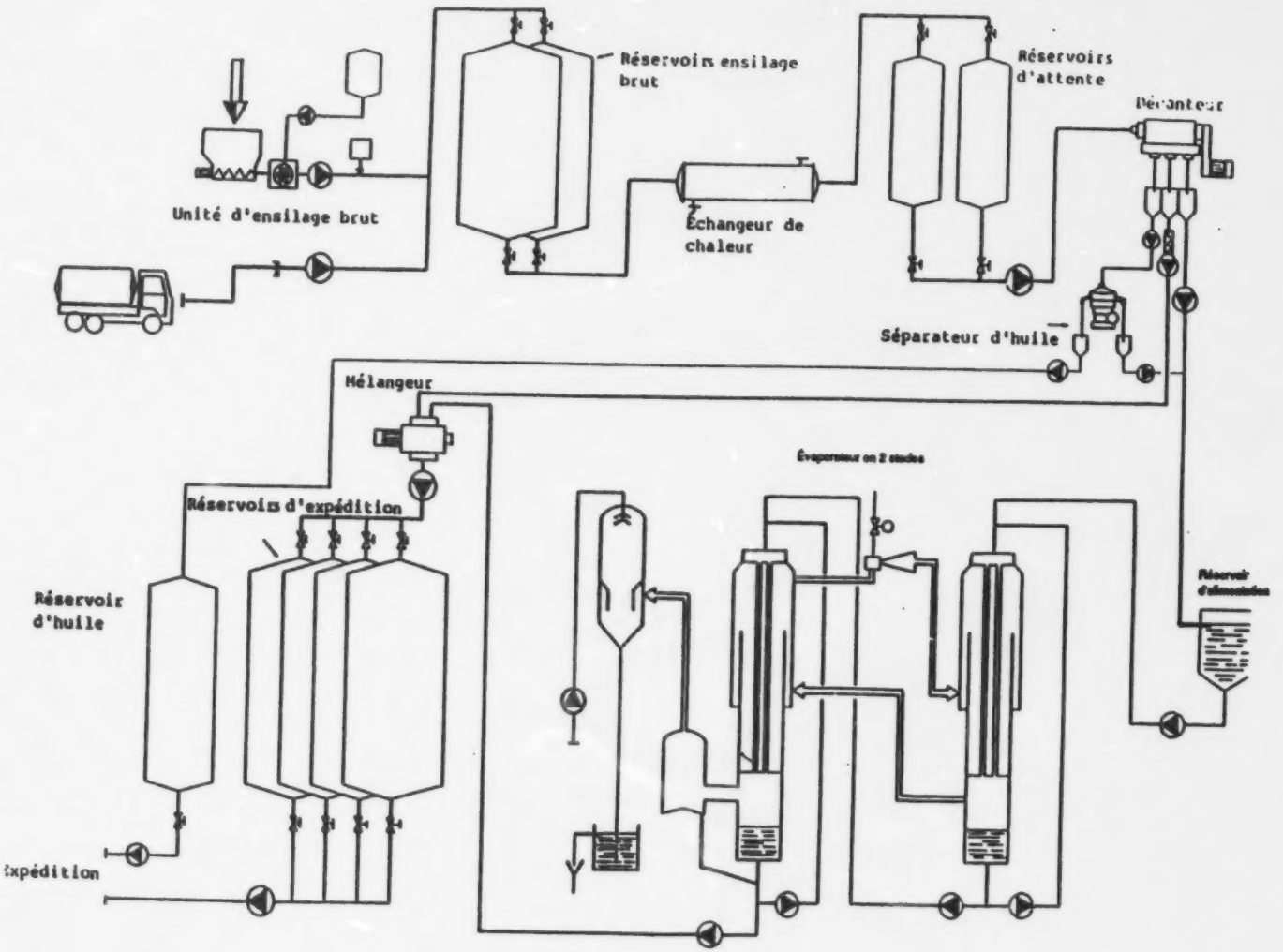

Fig. 16. Flow diagram for the silage refining unit

Table 16: Estimated production costs of concentrated herring silage (50% dry matter) for two production scenarios.

	Scénario 1	Scénario 2
Fixed costs		
Interests		
- equipment	118 755	118 755
- buildings and tanks	63 420	95 130
Depreciation		
- equipment	150 000	150 000
- buildings and tanks	35 000	52 500
Insurance	55 000	63 750
Maintenance	110 000	127 500
Administration	65 000	65 000
Total-fixed costs	597 175	672 635
Variables costs		
- Raw silage (83 $/t)	1 672 000	1 672 000
- Shipping (30 km at 0,065 $/t/km)	39 000	39 000
- Energy (80 kwh/t at 0,05 $/kwh)	40 000	40 000
- Heating	10 000	14 000
- Direct labor	73 000	73 000
Total variable cost	1 834 000	1 838 000
Total production cost	2 431 175	2 510 635
- value of oil (2 800 t at 250 $/t)	700 000	700 000
Cost of concentrated silage (7 600 t)	1 731 175	1 810635
Unit cost of concentrated silage ($/t)	227,79	238,24
Cost per ton of wastes processed	121,56	125,53

Unit production cost of concentrated silage (Table 16) was estimated by substracting from total production cost the stock value of oil produced. The total unit production cost estimated is 227,79 $ per ton of concentrated silage for Scenario 1 and 238,24 $ per ton for Scenario 2.

6.3.3 Viability of silage refining

Table 17 compares the cost of concentrated silage for potential users and the replacement value of the product. In Scenario 1, the cost becomes higher than the replacement value for users more than 750 km from the refining plant. However, in Scenario 2, he potential market for concentrated silage would be limited to a radius of only 400-500 km.

6.4 Dry silage production

6.4.1 Immobilizations

The following analysis is based on the hypothesis that fish meal plants in operation in northeastern N.B. are already equipped for drying raw fish silage. In this scenario, raw silage is processed according to the same flow chart as stickwater in Fig. 9. Raw silage is decantated and centrifugated to recuperate oil and solids and is evaporated before incorporation in the dryer.

Table 17: Comparison of the cost to potential users of concentrated herring silage and the replacement value of the product when substituted to fish meal

Distance between plant and user (km)	Replacement value[1] $/t	Cost to user[2] $/t	
		Scenario 1	Scenario 2
0	294,70	261,96	273,98
250	298,58	278,21	290,23
500	302,46	294,46	306,48
750	306,33	310,71	
1 000	317,97	326,96	

1. Replacement value = 80 % of cost of fish meal ($/kg of protein) shipped to destination (0,035 $/t - km) multiplied by the silage content in proteins (kg/t).

2. Cost to user = production cost + 15% + shipping cost (0,065 $/t - km).

Supplementary equipments required according to this hypothetic scenario are:

- one heat exchanger to heat silage before decantation and centrifugation
- tanks for storage of raw silage

For a fish meal plant with a capacity of 10 t of wastes per hour, the processing capacity would be of approximately 6 t of raw silage per hour, i.e. the same as the refining plant discussed above. In August and September, the fish meal plant processes in priority fresh wastes; tank capacity should therefore be in the order of 13 000 t according to Scenario 1. Supplementary immobilization cost are estimated at 1 250 000 $.

6.4.2 Production costs

Supplementary fixed costs for processing silage are estimated as follows:

- interest on tank	108 720 $
- interest on equipment	4 000 $
- depreciation of equipment	5 000 $
- depreciation of tanks	60 000 $
- insurance	31 250 $
- maintenance	62 250 $
- administration (1/2 of refining plant)	32 500 $
Sub-total	303 970 $

Variable costs are estimated as follows:

- raw silage (83,60 $/t)	1 672 000 $
- transport	34 000 $
- energy (250 Kwh/t)	250 000 $
- heating of plant and part of tanks	25 000 $
- manpower (same as refining plant)	73 000 $
Sub-total	2 059 000 $
Total	2 363 000 $

Supplementary costs for drying 20 000 t of silage are estimated at 2 363 000. With a stock value of oil produced fixed at 250 $/t, the unit cost of the 4 200 t of dry silage produced (10 % humidity) is estimated at 396 $/t.

6.4.3 Viability of drying silage

The above analysis is very approximative because is was difficult to evaluate all the implications of drying silage in present fish meal plants. Furthermore, the value of dry silage compared to fish meal is not known. This preliminary analysis suggests that drying silage in existing fish meal plants in northeastern New Brunswick could amortize the high costs of utilization of stickwater evaporators.

7. ECONOMIC ANALYSIS OF FISH WASTE COMPOSTING

7.1 Production scenario

The production of fish waste compost is made in a centralized unit that includes the mining of peatland. A maximum of 100 t of fish wastes per day are processed. According to Table 18, a total of 6 000 t of fish wastes and shelfishwastes (mostly crabs wastes produced in May and June) are mixed with 5 300 t of peat moss (50% humidity) to produce 15 000 t of compost (65% humidity). Operations cover a period of 7 months, from mid-April to mid-November. Peat moss is collected from mid-June to mid-August; it is used during harvest, stored outside to be used before the end of September or stored inside (1 500 t) to be used in spring. Fish waste processing starts in May, stops in July and continues from August to the end of September. The stabilization period starts 5 to 7 weeks after the initial processing. 100% of sales are made in Spring.

7.2 Immobilizations

Immobilization cost are estimated in Table 19. All costs are for new equipment. They do not include the costs for the preparation of a new peat field nor for access roads and electric lines. Preparation of the composting site includes the elimination of the vegetation layer, drainage, levelling and spreading of a gravel layer on a 5 ha surface. Compost screening and loading on trucks is made using a specialize vehicule.

Table 18: Production scenario for composting fish wastes in northeastern New-Brunswick

	Fish wastes entering process (t)	Peat moss collected (t)	Compost entering stabilization phase (t)	Compost screened and sold (t)
May	1 000	-	-	9 000
June	1 000	1 325	1 250	3 000
July	-	2 650	2 500	-
August	2 000	1 325	1 250	-
September	2 000	-	2 500	-
October	-	-	5 000	-
November	-	-	2 500	-
December	-	-	-	-
January	-	-	-	-
February	-	-	-	-
March	-	-	-	-
April	-	-	-	3 000
Total	6 000	5 300	15 000	15 000

Table 19: Estimated immobilization costs for composting fish wastes

	Cost ($)
• Peat land (50 ha)	37 500
• Peat moss collecting equipment	
- 2 tractors	60 000
- 2 aspirators	27 000
- 1 harrow	8 500
- 1 rotocultor	7 000
- 1 draining	5 000
- 1 back-hoe	75 000
	182 500
• Material mixing equipment	
- 1 feeding hoppers (100 t)	25 000
- 2 conveyors for wastes	10 000
- 1 grinder (15 t/h)	25 000
- 1 storage bin	10 000
- 1 endless srew	5 000
- 1 peat moss warehouse (1 000 t)	25 000
- 2 conveyors for peat moss	20 000
- 1 mixer (300 t)	25 000
- 5 hoppers for storage (20 t)	50 000
	195 000
• Water supply	
- 1 well	5 000
- pumps, pipes and vaporizers	15 000
	20 000
• Composting site, land (10 ha)	30 000
• Preparation of site	50 000
• Composting equipment	
- 2 wagons	35 000
- pipes, covers	100 000
- monitoring equipment	3 000
	138 000
• Screening and loading equipment	150 000
• Administration building	35 000
Total	838 000

7.3 Production costs

Immobilizations are financed by a 20 years loan for the land and buildings and a 10 years loan for equipments. The interest rate is 13% per year. Insurance cost represent 2,5% of immobilization cost and maintenance, 5% of these costs. Depreciation is 5% per year for building and 10% per year for equipments. Administration and marketing costs include the wage of a full time manager and of a part-time book-keeper as well as office expenses.

In this scenario, fish wastes are free but are shipped from fish plants at the charge of the compost producers.

Production costs are given in Table 20. The unit production cost is 26,81 $ per ton of compost, i.e. 67,02 $ per ton of fresh fish wastes processed, a cost comparable to ensiling.

7.4 Viability of fish waste composting

The only comparison basis possible for the evaluation of the viability of fish waste composting is concentrated silage. The cost for potential users of the two products is compared in Table 21. Compost can be compared to silage by taking into account only their content in fish waste (peat moss and water being inert matter). Using this criteria, fish compost is cheaper than concentrated fish silage for users within 200 km of the processing plant; however, because of the high shipping cost of compost, concentrated silage becomes rapidly cheaper than compost for distances higher than 200 km. The use of compost, like silage, requires specialized equipment for its application on agricultural land. Its use in green-houses is however more easy than silage. In general, compost is considered a better soil conditionner than silage.

Table 20: Estimated costs for composting herring wastes

	Cost (X 10^3 $)
Fixed costs	
Interests on equipment	52,3
Interests on land and buildings	16,1
Depreciation of buildings	3,0
Depreciation of equipment	66,1
Insurance	18,0
Maintenance	36,0
Administration and selling costs	55,0
Sub-total	246,5
Variable costs	
Fish wastes	00,0
Fish wastes shipping (0,10 $/t-km; 50 km)	30,0
Fuel	20,0
Electricity	5,0
Bio-activator (20 g/t X 30,00 $/kg)	9,0
Direct labor	
- 8 workers X 1 120 h X 8,5 $/h	76,2
- 1 foreman X 1 280 h X 12,0 $/h	15,4
Sub-total	155,6
Total cost	402,1
Unit cost ($/t of compost)	26,81
($/t of fish wastes processed)	67,02

Table 21: Comparison of the cost to potential users of fish compost and concentrated silage

Distance between user and plant (km)	Cost of concentrated silage[1]		Cost of fish compost[2]	
	$/t of product	$/t of fish waste in product	$/t of product	$/t of fish waste in product
0	261,96	115,91	30,83	77,08
100	268,46	118,79	40,83	102,08
200	274,96	121,66	50,83	127,08
300	281,46	124,54	60,83	152,08
400	287,96	127,42	70,83	177,08
500	294,46	130,29	80,83	202,08

1. See Table 17.
2. Cost to user = production cost + 15% + shipping cost (0,10 $/t-km).

8. DISCUSSION AND CONCLUSIONS

In the early 1980's, herring de-roeing has become a major activity of the fish processing industry in northeastern New-Brunswick. This type of processing done mostly in 6 to 8 weeks in late summer uses only 4-5% of the landed herring biomass. The remaining carcasses (95-96%) cannot be used for human consumption and not even as bait; they are presently processed into fish meal and oil or, in a lesser extent, are spread on agricultural land. However, the output of herring wastes in the region in late summer is to high that traditional users are incapable of absorbing it completely. About 50% of the herring wastes produced, i.e. 15 000 to 20 000 t, are discarded in land fill sites, in dumps or at sea at a cost of 20 to 40 $/t.

Herring wastes constitute a biomass rich in proteins and oils. Fish proteins have a very good reputation for animal feed producers because of their high level of digestibility. Fish oils which have a high content in omega-3 fatty acids are associated with the prevention of cardiovascular deseases. Furthermore, fish wastes have always been recognized as good soil fertilizers.

Many technologies are presently available for processing fish wastes into usable products. However, because a very large volume of herring wastes must be processed in a very short time, complex technologies requiring large investments would not be viable in the present northeastern New-Brunswick context. Indeed, the infrastructures needed to processed the fresh wastes must have a large capacity and this large capacity will be fully used only 6-8 weeks per year.

Two technologies with a good potential have been indentified for northeastern New-Brunswick; these are composting and ensiling. Composting consists in the controlled aerobic biodegradation of organic matter. The basic process in simple and does not require energy. Besides wastes, it requires air, water and a material rich in carbohydrates. Peat moss which is very abundant in northeastern New-Brunswick is a very good source of carbohydrates. Composting units could be installed beside fish plants but a more rational approach is to concentrate operations near the source of peat moss. However, automatized composting units with a capacity of more than 100 t per day are not presently available and the potential

market is geographically limited (300 km of fish plant) and vague. Therefore, composting does not represent an attractive short-term solution for the utilization of a very large proportion of herring wastes produced. However, the use of fish compost for conditionning potato growing soils should be investigated.

Ensiling is a simple method of preserving fish wastes. The ensiling units can be automatized and adapted directly at the end of the processing lines in fish plants. Raw silage is a stable liquid product that can be stored at a relatively low cost.

In order to insure a very good quality of the product and to eliminate problems associated with the transport of a polluting matter (raw fish wastes), silage should be produced at the same rate as the raw wastes in every fish processing plant. For a fish plant producing 1 000 t of wastes in late summer, the costs of the ensiling and storage equipment is about 175 000 $. This equipment should be used during all the operational season. the value of the silage produced in this plant could amount to 125 000 $ per year. For a fish plant producing 2 000 t of herring wastes in late summer, the cost of equipments is about 300 000 $ and the value of the silage could amount to 225 000 $ per year. Ensiling would not be viable for fish plants producing less than 1 000 t of fish wastes per year. Wastes from these plants should be processed in larger ensiling units.

Raw herring silage is a product with a high water and oil content. These characteristics limit its potential scope of utilization and the geographical scale of potential markets. Thus, it is often advantageous to recuperate the oil and to concentrate the de-oiled silage. Because the costs of refining equipments are relatively high, oil recuperation and silage concentration should be done in a centralized unit. A silage refining plant with a capacity of 20 000 t per year represents an investment of about 2,2 $ millions. The value of the refined products is evaluated at 2,5 $ millions per year.

For many potential users in eastern Quebec ant the Maritimes, the cost of raw or refined fish silage when substituted to fish meal or to grinded-frozen wastes could be advantageous. Potential markets representing 63 000 to 74 000 t of raw silage per year were identified in this part of Canada. However, the penetration of these markets by fish silage produced in northeastern New-Brunswick could be difficult for the following reasons:

- potential users do not know the product;

- many potential users are not equiped to manipulate the product;

- other fish waste producing areas are sometimes closer to potential markets.

Furthermore, fish silage will represent an attractive alternative for potential users only if the folling conditions are met:

- silage of a constant and very high quality;

- constant and regular supply of silage from year's end to year's end.

This represents an important challenge when one considers that many independant ensiling units would be involved and that fish landings may fluctuate considerably.

In agriculture, the potential of fish silage appears huge. However, the scale of these markets is presently vague because the value of the product for potential users is difficult to evaluate.

On a short term basis, the markets for raw and concentrated fish silage will probably not be able to consume all unutilized fish wastes produced in northeastern New-Brunswick. Therefore, the possibility of drying raw silage in the existing fish meal plants of the region should be investigated. Presently, the technical feasability of this approach and the value of dry silage are unknown.

Table 22 gives the estimated costs of different alternatives for the disposal and utilization of fish wastes in northeastern New-Brunswick. For a fish processing plant, the cheapest method of disposal is to ship wastes to fish meal plants; application on agricultural land, landfilling and dumping at sea follow in order of increasing costs. The cost for composting and for ensiling wastes are similar. The cost for reduction into fish meal, for ensiling/refining and for grinding/freezing wastes are similar. With all these processing methods, the value added to wastes is in the order of 110,00 $ to 160,00 $ per ton.

Table 22: Comparison of estimated cost of various fish waste disposal and utilization alternatives for northeastern New-Brunswick

	Cost per ton of waste ($)[1]	Value of product per ton of processed wastes[2] ($)	Remark
• Shipping to fish meal plant	5 - 20	0	
• Dumping at sea	35 - 50	0	
• Land fall	20 - 30	0	
• Spreading on agricultural land	10 - 20	0	
• Grinding-freezing	130 - 140	140 - 160	FOB freezing plant
• Fish meal reduction	100 - 120	130 - 150	FOB plant
• Ensiling	65 - 85	110 - 115	FOB plant (estimated)
• Silage refining	120 - 125	145 - 150	FOB plant (estimated)
• Composting	65 - 70	100-125	FOB plant (estimated)

1. Includes transportation costs to processing site.

2. Equivalent to added value to wastes.

9. RECOMMENDATIONS

Ensiling or composting fish wastes can not eliminate on a short term basis the problem of herring waste disposal in northeastern New-Brunswick because potential users of silage and compost are not presently ready to buy these products on a large scale. In order to develop the markets for these products, it must be demonstrated that they can be produced with a constant and excellent quality, that their use brings more advantages than inconvenients and that they can be produced at an attractive price. Thus, the development of ensiling and composting facilities must be gradual. A first pilot phase (1-2 years) must aim at the development of markets, with pilot scale infrastructures used to master the processing technology, to determine with precision production costs and product characteristics and to produce volumes required for large scale trials of the products by potential users. It is therefore recommended to conduct in 1989-90 the following activities:

1. Setting up of a typical ensiling unit in a typical herring de-roeing plant. Pilot production is surveyed by a scientific team in order to adjust processing variables, characterize the product and determine production costs. Production is about 1 000 t of raw silage; immobilization costs are estimated at 175 000 $.

2. Setting up of a pilot scale silage refining unit for oil extraction and concentration of silage. This unit has the capacity to process 300-500 t of raw silage per year; immobilization costs including a laboratory are estimated at 200 000 $.

3. Trials on the utilization of silage in cooperation with potential users:

   Raw silage:
   - Salmon feed
   - Fox and mink feed
   - Fish meal plant

Concentrated silage:
- Salmon feed
- Fox and mink feed
- Hog farms
- Canned pet food
- Horticulture
- Potato growing
- Methanization

Dry silage:
- Dry feed in general

Oil:
- Salmon feed
- Fox and mink feed
- Industrial users
- Fuel

4. Setting up of a pilot scale composting unit (capacity of 1 000 t per year). Immobilization costs are estimated at 150 000 $.

5. Trials for the utilization of fish compost in cooperation with potential users.

   - Potato growing
   - Horticulture

6. Development within the New-Brunswick Government of an expertise in the field of underutilized biomass valorisation.

ANNEX 1

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ANNEX 2

Fish processing plants surveyed in the present study

- Albert and Son's Fisheries
- Atlantic Sea Harvest
- Ass. Co-op des Pêcheurs de l'Ile
- Baie Chaleur Packer Ltd.
- Blue Cove Packing
- Bulger Fish Market
- Canadian Ocean Products
- Carapro Ltée
- Duguay M.O. Ltée
- Ellis Seafood Ltd.
- Gauthier L.L. and Sons
- Maisonnette Seafood Ltée
- Marché de poisson Landry inc.
- McGraw Fruits de Mer Ltée
- M.P.Q. Ltée
- Morue Impériale Ltée
- Ocean Flow Seafood Ltd
- Pêcheries Alfo Ltée
- Pêcheries Caraquet Ltée
- Pêcheries F.N. Ltée
- Pêcheries Garo
- Pêcheries Roma Ltée
- Pêcheries Saint-Paul Ltée
- Poissonnerie Arsenault Ltée
- Poissonnerie R.G. Cormier
- Poissonnerie Savoie
- Produits Belle-Baie Ltée
- Produits de la Pêche A. Jones Enr.

ANNEX 3

Companies involved in fish waste utilization in northeastern New-Brunswick

Association coopérative des Pêcheurs de l'Ile	Reduction into fish meal and oil
Blue Cove Packing, Maisonnette Seafood	Ensiling (started in 1988)
Produits du Golfe Saint-Laurent	Reduction into fish meal and oil
Pêcheries FN Ltée	Reduction into fish meal and oil, ensiling (started in 1988)
Elles Sea Food Inc.	Composting (started in 1988)